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ABSTRACT

The purpose of this study was to perform pilot research upon two normal children aged six years (an age midway between complete absence of time conceptualization and maturation of time concepts) in order to chart the characteristic responses within a conditioning paradigm. Previous literature in the field is reviewed for the purpose of providing a rationale for the use of autonomic variables (galvanic skin response and cephalic vasomotor response) and a delay conditioning procedure. Special attention was devoted to development of a testing technique which would overcome fear of the test situation and equipment. Testing procedures was divided into the following phases: (1) habituation, (2) temporal conditioning, and (3) post-conditioning test series. Both subjects displayed a far better ability to inhibit responding, even during extinction, than was anticipated. The possibility of counting behavior was controlled. A discussion of the various test factors concludes that the use of the current equipment and procedure can be expanded into a larger, cross-sectional project to establish normative profiles of temporal discrimination. Test charts of the subjects' responses are included. [Not available in hard copy due to marginal legibility of original document.] (Author/NH)

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THE DEVELOPMENT OF TEMPORAL DISCRIMINATION
IN YOUNG CHILDREN

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June 1969

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LITERATURE REVIEW

1. Directions of Research in Time Perception

Although "time" is so elusive a concept- so difficult to pin down or define- the perception of its passage is an undeniable faculty of humans and suprahuman organisms alike. With Mach's (1886), insightful writings on the existence and nature of a subjective, psychological time, modern investigations of the subject have tended to fall into several basic categories: 1. a search for chemo-physiological mediators and correlates, 2. an investigation of the beginnings of temporal expectancy in infancy and the development of timing concepts in children, 3. a linking of time perception to time-related internal rhythms or "biological clocks", 4. the evolving of mechanical models capable of temporal mediation, 5. a charting of behavioral indicators of time perception in normal and abnormal subjects under a variety of conditions, and 6. the quasi-philosophical inquiries into the nature of time itself.

2. The Relative Importances of Objective "Real" Time and Subjective Perception of Time.

It has been suggested that "time" has no existence in the real world - that it is a superimposed, event-ordering phenomenon only. For purposes of this discussion, such a construct is not viewed as useful, anymore than to maintain that "umbrella", "red" and "middle C" do not exist in the real world or, more stickily, "unicorn". Rather, let us grant that in the final analysis, all perception is an ordering phenomenon. What seems relevant here, is that incoming events, (stimuli), when received in appropriate combination by an

organism possessing normally functioning recepto-processing mechanisms of adequate range and sensitivity, come together to form a distinct perceptual entity, capable of isolation by the organism from the environment as a whole, and finally, this perceived entity is further capable of eliciting a response where similar stimulus collections, (combinations), fail to do so.

There is every evidence in and out of the laboratory, that we receive and process "temporal" input - i.e., input which is translatable into order, interval, and duration - as reliably as we receive and process input to the known modalities. One of the central questions concerning us here is whether time perception should be viewed as a primary or an accessory process- a passive or and active process.

3. Time Receptors

The view expressed by Pavlov(1927), and only recently challenged experimentally, regards time sense not as a discrete process, but rather as a functional part of processing in the known modalities. Current work being undertaken, however, indicates that there may indeed be neurons whose initial firing rates and delays are temporally contingent, and unrelated to external sensory input (Liebeskind, 1968). The implications for time perception of such neurons are, as yet, unclear.

While some investigators have regarded time perception and time storage as a passive, hole-in-the-donut-correlate to events, others have regarded it as an active, discrete process, complete in its mediation, whose breakdown may lead to profound pathological consequences, particularly for the human organism, (Cohen, 1967, Frolov

1951, Treisman 1963, Richter 1965, & Cornwall 1968).

Indeed, some of the most intriguing observations regarding time perception have involved individuals with known pathologies, whose temporal recall appears aberrant, even though the original storage is believed to have been normal. This phenomenon has long been associated with senile psychosis (Cohen 1967), Penfield (1934) describes aberrations of temporal recall in epileptic patients having temporal lobe lesions - both during the march of symptoms leading up to seizure and under conditions of inter-cranial stimulation. The state is characterized by an abnormally protracted déjà vu.

As this discussion moves further, we find it necessary to make a clear distinction between "subjective time" and "timing" or time reproduction, for the distortion of subjective time in an abnormal individual by no means indicates an automatic loss of accuracy in many time discrimination tasks. Neither, Cappon & Banks (1969), Ehrental & Jenny (1960), Lhamon & Goldstone (1956), nor Warm, Morris, & Kew (1963) found any difference between psychotic schizophrenics and normals on time reproduction tasks, even though reports of extreme distortions of subjective time were obtained from the schizophrenics. Mezey & Cohen (1961) have observed a like pattern for hospitalized subjects suffering from depression. Orme (1962, 1964), however, gained results at odds with the other studies, which indicated that schizophrenics and depressed neurotics were significantly less accurate than normals on a time estimation. This apparent conflict of results points up the importance of careful consideration of the effects of the method in obtaining data. The method of estimation

is primarily dependent upon verbal mediation and is therefore intimately related to conceptual timing mechanisms. Thus, this method is contaminated by conceptual aberrations as evidenced in schizophrenics.

When compared to the above studies, a second set of experimental manipulations have yielded different results: under conditions of sensory deprivation, drug administration and the alteration of the internal environment, both subjective time and temporal discrimination appear affected. Banks & Cappon (1962), Francis (1964), Ochberg & Meyer (1965) & Vernon & McGill (1963), utilized sensory deprivation in a variety of experimental designs and all found a tendency of subjects to underestimate time passage, and to perform less accurately than non-deprived controls. Reed & Kenna (1964) have conducted studies involving the selection of certain personality variables and have found a correlation between scores on the Mandsly Personality Inventory Extroversion Scale, and time estimation under conditions of sensory deprivation. Extroverts were found to be significantly less accurate than introverts.

Hoagland (1933) discovered that as internal body temperature increased as the result of fever, that the estimation of a minute became correspondingly shorter for his one subject. Bell (1965) was unable to reproduce Hoagland's results and found no effect on timing accuracy for normal subjects placed in hot water. It is extremely difficult to compare these two studies in the light of central control mechanisms of body temperature regulation. The hypothalamic structures controlling thermic homeostasis are little effected by external temperature variations as it reverts to peripheral mechanisms for maintaining thermic balance, e.g. sweating,

vasoconstriction, and dilation, etc. In the fevered state these hypothalamic structures are seriously affected as they function to maintain higher temperatures implicated in the bodies reaction system for control of certain disease states. Kleber, Lhamon & Goldstone (1963) found that estimations of 1 second stimulus durations were overestimated by hyperthermic and hyperthyroid subjects - in contradiction to the findings of Hoagland and Bell.

The reports of drug studies in the literature of time perception deal primarily with distortions of subjective time rather than with investigations of time discrimination. In their classic works on the effects of opium, Cocteau (1729), De Sade (1792), and De Quincy (1866), report distortions of subjective time, as does Baudelaire (1860) for hashish, Bromberg (1934) for marijuana. Boardman, Goldstone & Lhamon (1957) report both subjective distortions and changes in time estimation under LSD-25, and under the serotonin precursor, 5-hydroxytryptophan. Wharburton & Russell (1968) found that rats trained on a 30 sec. S-R schedule were able to readjust their responses when the interval was shifted to other durations. However, rats injected with 8-azoguanine immediately before the interval was changed, demonstrated a considerable delay in change of response rate which was correlated with concentration of the drug. This and other supporting evidence are consistent with the hypothesis that "inhibition of protein synthesis in the hippocampus resulted in the impairment of learning and in cellular changes observed histologically two weeks later."

As noted earlier, some of the work in time perception has

revolved around the existence of bio-rhythms and physiological clocks. Much of this literature is concerned with the development of circadian rhythms, or rhythms that recycle every 24 hours, and has been thoroughly reviewed by Cloudsley-Thompson (1961) and Wolff (1967).

Richter (1965) has put forth the theory that biological clocks are operative at three levels: 1. homeostatic clocks involving feedback control (hormonal), 2. central clocks operating almost independently of external or internal change, and 3. peripheral clocks located outside the CNS and controlling limited areas, e.g., tissue and organ cyclical activity. Halberg (1960) has shown that multiple physiological functions are correlated in terms of their cyclical activity, and developmentally, Hellbrugge (1960) has found that while very few physiological rhythms exist at birth, definite diurnal variations do appear in skin resistance by week one, in temperature by 4 weeks and in heartrate by 6 weeks. Lobban (1965) has demonstrated that sleep-wakefulness cycles are established within the first week after birth. As a result of the effects of sensory deprivation upon time perception, however, Francis (1964) and Vernon & McGill (1963) have argued against any functional connection between these physiological clocks and the perception of time.

Studies on the relationship between ablation and time discrimination are too few to be considered conclusive. Ellen, Wilson & Powell (1964) found that septal lesions produced impaired learning of a temporal discrimination task in rats. Diamond (1964) reported impaired planning activity in humans with pre-frontal ablations (which may be attributable to loss of motivation, as this was not controlled for), and impaired serial learning in frontally ablated

rats and monkeys. In addition, he found, (1967), a loss of ability to discriminate changes in the temporal patterns of auditory stimuli where portions of the auditory cortex had been ablated. This is especially interesting in light of the findings of Goodfellow (1934), that intervals are reproduced more accurately when the standard is auditory than when it is visual.

In other studies seeking physiological mediators and correlates of time perception, Hawkes (1961) has demonstrated the effect of altering autonomic variables, (heart rate & blood pressure), upon the estimates of time, and views these variables as correlates of time experience.

Lockhart (1966) has temporally conditioned the galvanic skin response in adults demonstrating that both its acquisition and extinction follow characteristic gradual and constant increases and decreases in amplitude, as in conditioned motor responses.

Fernandez-Guardiola et al. (1967) presented subjects with a monitoring task on a FI schedule and concluded that deterioration of a required discriminative response was accompanied by a decrement in the attenuation of alpha rhythm of the EEG and a slowing of heart rate. Although, optimal performance was characterized by a "predictive" brief attenuation of alpha rhythm just prior to the termination of the FI. This was considered a sign of "expectancy".

Cornwall (1967) has found in sleeping rats that when classically conditioned with 10 sec. between the ECS termination and a UCS onset, arousal is delayed by an amount of time approximately equal to the conditioned interval without affecting the sleeping EEG in either the cortex or the tegmentum. This suggests that even during the low

level of arousal characteristic of sleep, some process can continue in the brain and many seconds later trigger a clock-like awakening from sleep.

Weinberger & Lindsay (1964) have observed behavioral arousal and electrocortical desynchronization to stimulus offset as well as onset in sleeping cats. Konorski (1948) has suggested that what occurs during temporal conditioning is "that the moment immediately preceding the UCS becomes an active CS, and the more remote moments are differentiated and become inhibitory stimuli. It is possible that Liebeskind's previously discussed constant low-frequency posterior thalamic nuclei neurons may be inhibited, except for that one leading to reinforcement.

4. Clock Models

Just as the above investigators have searched for physiological mediators of time perception, Hoagland (1933), Treisman (1963) and finally Cohen (1967), have attempted to construct clock models along functional lines with an interesting degree of predictive capacity. Hoagland has suggested a "chemical clock" and compared it to pacemaker neurons. These produce impulses at rates which vary, and transmits them along axons whose speeds of conduction are relatively fixed. Treisman (1963) in a study which fits a good deal of the results of time perception studies and associated phenomenon to an interesting model has expanded upon Hoagland's pacemaker. He has proposed an ingenious model of psychological time which has three components; a pacemaker (proposed by Hoagland), a counter and a store. The pacemaker emits a continuous and regular series of pulses. The

counter, in measuring an interval of experienced time, records the number of pulses passing a given point on the path leading from the pacemaker. Finally, this number is transferred from the counter to a store, which may retain the information in logarithmic form. Measures in the "store" can be retrieved by the "Comparator", (decision mechanism), which compares retrieved measures with current counts made by the counter and selects responses from the "response mechanism" to make. A "verbal selective" mechanism acting on the "store" assists in retrieval, and a "specific arousal center" acts on the "pacemaker" and can modify its rate.

In Cohen's refinement of the model, the specific arousal center is replaced with a series of "calibrating monitors" which correspond to "other experiences undergone during the temporal experience". A "variable pacemaker(s)" is stressed as is a "variable projector" and a "variable counter". The "variable projector" is added to account for the "rate at which experiences are projected into awareness when we recall them", as well as the rate at which they are initially recorded. Needless to say, the value of such theorizing as Cohen's is minimal as far as throwing any light upon the actual substrates of time perception. Treisman's model however, if remembered that it is only a model, does suggest some measurable, mathematical relationships existing between elements of the temporal process.

Smythe & Goldstone (1957), in observing that short intervals (1 sec.) tend to be overestimated whereas longer ones tend to be underestimated, have suggested a "pacer" with greatest accuracy at about 1-2 seconds, possibly implicating heart rate control centers.

5. Developmental and Comparative Studies

As noted earlier, the developmental aspects of time perception have been approached from several different angles: 1. the first appearance of conditionable expectancy in infancy, 2. the development of skill in temporal reproduction and estimation tasks, and 3. the growth and refinement of time conceptualizations.

Marquis (1941) found gross motor activity related to feeding schedule to be conditioned by the 9th day of life. Krachkovskaia (1959), found a conditioned rise in leukocyte count temporally linked to feeding schedule, and appearing about the 8th day after birth. The work on pupillary conditioning (Brackbill 1941) with neonates as well as that on the development of physio-rhythms has already been discussed.

Brackbill (1961) in reviewing much of the literature on developing time discrimination, has summed a good deal of it up by, "younger children use knowledge of results to improve their time estimates less effectively than do older children" (Smythe & Goldstone 1957), but, in addition, "time discrimination is less accurate in younger children than in older children, and less accurate in older children than in adults" (Axel 1924, Gilliland & Humphreys 1943, and Smythe & Goldstone 1957) .

However, evidence for the early appearance of the capacity to wait, or establish the basis for temporal expectancy, has been demonstrated by Hunter in that children as young as 4 years could delay a reaction for 30 seconds.

As for the development of time "concepts" in children, Piaget (1946, 1955, & 1966) has maintained that these concepts must be preceded by concepts of "speed and space". In this regard, he makes an important distinction between two aspects of time concept-

ualization; 1. sequence (ordering), and 2. duration by which he means inter-event interval.

Fraisse (1963) on the other hand claims that a child has a "primary intuition" of time on a par with those of speed and distance,-- and is related to the basic interval between his awareness of a need or wish and its fulfillment or attainment. In Fraisse's view, therefore, a need state and expended effort are the first links in the conceptual chain leading to temporal concepts.

Ames (1946) has discovered a hierarchy of conceptual refinement in the developing child which, while variable as to absolute age, is believed to be sequentially consistent. Her hierarchy is dependent upon language development, and is shown to be roughly, "today" (24 mo.), "tomorrow" (30 mo.), with "yesterday" being verbalized last at around 36 mo..

It is unfortunate that there are no systematic studies in the literature of time perception in organisms ranging down the phylo-genetic scale through which we might gain knowledge about the biological development of non-verbally mediated time perception. Woodrow (1928) taught monkeys to differentiate between temporal intervals of 1.5 to 4.5 seconds with an accuracy of 90%. Honzig (1931) conditioned a 45 second behavioral delay in rats and Gerall & Obrist (1962) employed cats in a temporal conditioning paradigm. Pavlov's (1927) studies in this area, while numerous, are limited to relatively few animal species. Beyond this, there is little comparative work, except in the area of learning with work employing a FI schedule of reinforcement and subsequent response patterns. It seems reasonable to suggest that any organism whose response patterns are capable of

being brought under the control of a FI schedule, is capable of time perception, although its limits and degree of refinement remain uncharted.

Krupp (1961) has expressed the importance of methods on the results obtained in time perception studies. He concluded that Reproduction was the most accurate and least variable method, followed by Estimation, with Production in last position for both variability and accuracy.

These three methods have been described by Woodrow (1951);

1. Estimation. (A verbally mediated process).

"How long was that interval?" the experimenter, (E), asks the subject, who responds in "seconds or minutes."

2. Production.

Subject creates an interval of a verbally specified duration, i.e., by tapping at 1/sec.. (This method is also verbally mediated.)

3. Reproduction. The subject reproduces a standard interval produced by the experimenter first.

The Soviets have often employed a variation of the Reproduction method inherent in a classical conditioning paradigm. This technique has been most extensively used by Luria (1963) in the study of language development in children and semantic conditioning. Luria and also Zaporozhets (1961) have used selected autonomic variables, in conjunction with a classical conditioning paradigm in children. The use of photoplethysmograph and galvanic skin response has served as an extremely valuable index of the development of conditioned connections between stimuli.

The existing body of literature in time perception is sketchy at best and usually only loosely related in terms of objectives and methodologies.

The above review has been an attempt to provide a brief survey of only the major areas of this body. In addition to this material, a cursory review of a second related area would be essential. As an initial objective of this pilot study is to delineate the existence, development, accuracy and stability of central timing mechanisms in the human, it is essential to use a methodology containing a minimum of bias involving changes in conceptual growth. The temporal conditioning of several autonomic indices would provide this type of control. Wedded with a time discrimination task requiring no verbal mediation, this approach would provide optimally unbiased data for cross-sectional research.

Research using autonomic indices of conditioning and expectancy (a temporally conditioned response), is by no means of recent origin. Lacey (1958) has used changes in heart rate to differentiate responses to various categories of stimulation. Graham (1966) has also studied heart rate changes to stimulation, but has interpreted these changes as functionally representative of the "orienting reflex". The "orienting reflex" was originally observed as an experimental artifact in the work of Pavlov (1927), who labeled it as such. It seems as though an animal's response to extraneous stimulation during a conditioning procedure would totally disrupt the rate of acquisition. The animal would perk up his ears and turn his head in the direction of the novel stimulation, in a "what is it?" fashion. This is essentially what the orienting reflex is; "an attending to novel or unexpected stimulation". Correlates of this behavioral attending

have been most extensively explored by the Soviets who have observed multiple autonomic indices as well as cortical activation. → Germana (1964), Voronin (1960), Sokolov (1963), Lovibond (1969), Germana (1969). American investigators who have made heavy use of the autonomic indices in studying cognitive processes have included: Dykman (1959) (with careful attention to reactions to novel stimulation); Lewis, has utilized (1967) differential cardiac responses to study the differences between effects of auditory and visual stimulation in young children. An autonomic variable of considerable popularity in American research has been the galvanic skin response. This is probably attributable to its ease of obtaining, measuring, and reducing. In addition, research has indicated that it follows a fairly predictable pattern of acquisition and extinction Bierbaum (1958). Kimmel (1964) has used the GSR to study disinhibition as a function of the number of CS-UCS trials and temporal location of the novel stimulation.

Shmavonian (1959) has utilized the vasomotor response in conditioning in human subjects. This measure has proved of extreme interest, particularly to Soviet scientists, due to its bi-phasic nature. Vasodilation has been associated with attending to novel stimulation and has been observed during periods of problem solving and anticipation. Vasoconstriction, on the other hand, has been associated with situations of stress or threat. Classical conditioning involving aversive stimuli elicits a peripheral vasoconstriction. Sokolov (1963). Prout (1967) has demonstrated an apparent independence of the GSR from this vaso-constriction reflex in humans. However, there is still some question as to the

correlation between vasodilation and the GSR. Some work has suggested that under carefully controlled conditions there exists a marked interdependence between these two autonomic variables. (Maltzman)
1967

It seems extremely important to consider a possible bias existing in one of the most recent papers using an autonomic indice in children and adults. Brackbill's work in temporally conditioned pupillary reflex in neonates could not be extended to adults. However, this may be a property of the selected reflex rather than the absence of a centrally conditioned response in the adult subjects. This is highly probable in the light of Lockhart's (1966) success in temporally conditioning adult GSRs.

Thus, perhaps a more reliable and sensitive charting of temporal conditioning could be obtained in a cross-sectional study by the use of multiple autonomic variables. This is one of the rationals behind the methodology of this pilot study,

INTRODUCTION

The essential goal of this study was to perform pilot research upon normal children at an age midway between complete absence of time conceptualization and maturation of time concepts in order to chart the characteristic responses within a conditioning paradigm. Six years was selected as optimal to begin with for the following reasons:

1. Susceptibility to verbal instructions is present;
2. There exists an ability to inhibit responses or delay for reinforcement;
3. There exists only a moderate level of time conceptualization;
4. It would be unlikely that this age group would resort to a more sophisticated pacing or counting behavior to anticipate the presentation of a stimulus.

The justification and rationale for the use of both autonomic variables and a delay conditioning procedure has been explored already in the previous section.

The initial objectives of the present study are:

1. To determine if the proposed experimental paradigm and specially-constructed equipment are adequate to chart the acquisition, stability, and extinction of temporally conditioned autonomic indices.
2. To evaluate the feasibility of obtaining autonomic measures from young children. In that children seem to

display an aversion and fear to test equipment and situations, perhaps due to medical associations, development of technique to overcome this fear is absolutely and obviously essential. In addition, the effects of extensive movement, electrode placements, and fatigue are critical areas to be considered in approaching any reliable work in this area.

3. To explore the patterns of habituation and reinstatement of two selected autonomic variables, galvanic skin response and cephalic vasomotor response (photoplethysmograph technique) to temporal conditioning in children.
4. To examine the durability of a temporally conditioned response placed upon extinction.
5. To delineate the relevant differences between an autonomic response mediated by expectancy or anticipation and one mediated by a violation of expectancy.
6. And finally, to compare the two autonomic variables within the conditioning design.

Future research will attempt to expand this work into a cross-sectional study of two phases. The first will entail the collection of normative data on three-to-nine year old children. This research will form a comparative basis for subsequent work upon autistic children of an equivalent age range. It is possible that this technique may provide an extremely valuable approach to the study of perceptual mechanisms and aberrant processing in many childhood psychopathologies.

METHODS

Subjects

Subjects were two normal children, male and female, both age, 6 years, selected from the Anderson School.

Design and Procedure

The procedure was divided into three phases: 1. an habituation condition, 2. a temporal conditioning phase, and 3. a post-conditioning test series.

In Condition I the S. was presented a two second visual stimulus pattern at previously selected random inter-stimulus intervals from 16 sec. to 30 sec.. The purpose of this phase was to determine the rate of physiological habituation to a non-signal stimulus. Trials in this stage were presented until criterion of three successive stimuli failed to elicit an autonomic response of the GSR.

The only initial instructions given the subject were to inform him that we were going to play a game that would be lots of fun. He was, after preparation of electrodes, etc., instructed for the Cond. I to sit still and see what happens in the box.

The second condition, the temporal conditioning phase, consisted of a visual stimulus pattern (bulls-eye) which was terminated by the subject's pressing a button directly below this stimulus. Fifteen seconds later the second visual stimulus occurred for two seconds with a simultaneous presentation of a candy "M&M" reinforcement. (Refer to Event Diagram 1.) The $S_1 - S_2^{R+}$ trial was followed by a random previously selected intertrial interval (ITI) ranging from 15-45 sec..

The S was presented with conditioning trials until the magnitude of the GSR to S_2 was greater than to S_1 , on at least two consecutive trials. The only instructions given the S at the beginning of Condition II was to "press the button only when S_1 came on and watch to see what happens."

The third and final condition was the critical test phase. The subject could terminate S_1 by depressing the response button; however S_2 would not come on to cue the subject of reinforcement delivery. Reinforcement was also withheld in this condition, (except for reinstatement trials). This non-appearance of S_2 and R^+ constituted a violation of expectancy. The subject was not told of the passage from Condition II to Condition III. The randomly assigned inter-trial intervals were the same as in Condition II. The test trials of Condition III were interspersed with reinstatement trials. These were merely $S_1 - S_2^{R^+}$ trials as in Condition II. Reinstatement trials were instituted on about a 1:3 ratio with test trials.

The selection of a 15 second inter-stimulus interval, $S_1 - S_2$, was based on a careful previous study of what constituted an adequate time period for these two selected autonomic variables to respond to stimulation and return to baseline, or recover. The computed average was about 10 seconds. Thus, by allowing 15 seconds, ISI, an unadulterated record of responses to both stimuli could be obtained.

Condition III lasted approximately 15 trials. (The whole experiment was kept below 30 minutes from initial preparation to removal of electrodes.)

Preparation Procedure and Instructions

Subjects were brought into the special experimental van and seated comfortably in a specially constructed, attractive, blue

test chair, and faced the stimulus apparatus. (See Fig. 2)

The E at this time said, "We're going to play a really fun game, that I told you about. There'll be candy for you as part of the game. To start, we'll lay these buttons on your foot and leg.

These are the same kind of buttons that astronauts wear, and then

Then we can start the game." The skin of the plantar surface was

gently cleansed with a cotton alcohol wipe. The electrodes and PPG

recording transducer were fastened onto the subject as follows:

Two Beckman GSR electrodes were plantar placed, with one on the

plantar surface of the sole of the right foot and the other placed

about 4 inches above the ankle of the same foot on the inside of the

calf. A small photoplethysmograph transducer, about 1 inch by $\frac{1}{2}$ inch by $\frac{1}{4}$ inch was placed on the child's right temple with an adhesive ring.

The subject was instructed to sit very still and not move or talk. The habituation series of Condition I was started by the E saying "Watch the box and see what happens".

During this time, key behavioral measures of the S were recorded including, Eye-to- S_1 contact, Eye-to- S_2 contact, reaching for button, & reaching for reinforcement.

After habituation the S was then instructed to watch the experimenter and "do what he does." E waited for S_1 and then reached and depressed the stimulus button. He then looked to the right stimulus and waited. 15 seconds later S_2 and R^+ were presented and E picked up the R^+ and ate it. The S was then instructed to do the same thing that the E had just done. It took one S 5 trials before imitation was acquired and the 2nd subject 3 trials.

Apparatus

The stimulus and reinforcement device was designed and constructed by the E in the Psychology Dept. shop. (Refer Fig. 2)

It consisted of a plywood chamber 26" x 23" x 18" painted dark blue. The face of the chamber had, to the left of center, at 8" from the bottom and 3" from the left side, a replaceable frosted plastic stimulus panel, S_1 , 4" x 4" with a black and clear checker-board pattern of $\frac{1}{2}$ " x $\frac{1}{2}$ " squares. 2" directly beneath this stimulus was a red 1" plastic round button. On the right side of the front face of the stimulus box was a second stimulus plate, S_2 , 4" x 4", having a bulls-eye pattern of $\frac{1}{2}$ " alternating clear and black rings. This was 3" from the right side of the chamber and 8" from the bottom of the box. 2" below this was a square opening 3" x 2". Attached to this was an inside receptacle which caught the reinforcement and from whence the S retrieved his reward. Reinforcement was delivered via a Davis Universal Feeder inside the chamber. Each stimulus panel had 2 6V. D.C. test bulbs behind them, providing moderate illumination of the panel upon each stimulus presentation. Each element of the stimulus device was carefully selected to optimize rapid and efficient learning. The two stimulus patterns were selected in the light of Fantz's (1951) work demonstrating neonatal form preference for checker-board and bulls-eye patterns. The red response button was chosen to insure maximal attention and placed immediately adjacent to the stimulus, S_1 , cueing the button response. The reinforcement receptacle was placed immediately under the S_2 to optimize generalization of reinforcement properties to S_2 .

The programming of stimulus durations, interstimulus intervals, and reinforcement delivery was achieved with four Davis Interval Timers, connected into the appropriate programming sequence. The Intertrial intervals were generated by hand with a stopwatch and according to a preselected random schedule.

Electrodes were Beckman 1 cm. bio-electrodes used with IMI ZnCl electrode paste.

Physiological recordings were obtained on two channels of a Grass Model 5 polygraph, at chart speed of 6 mm/sec..

60 micro amps of current were passed across the GSR electrodes from the Grass Low Level D.C. Pre-amplifier, designed to take GSR. The PPG (photoplethysmograph) device was constructed by the E according to a modified schematic originally designed by Wenger (1948), and adapted to our equipment. The input of one of the Grass's D.C. amplifiers was used for the PPG and adjusted to a sensitivity of 100 mv/cm.

In addition, to the physiological measures and events, S_1 , S_2 and R^+ , recorded on the polygraph paper, these events and other previously mentioned behavioral measures were recorded on a 20 pen Esterline-Angus event recorder.

All programming, behavioral, and physiological recording equipment were separated from the experimental portion of the van by a sound-proof wall. The wall contained a one-way observation mirror of 36" x 24" dimensions.

A carefully kept continuous log was maintained on the study to record any deviations from procedure or any unusual events or problems.

Data Reduction

The physiological data was reduced according to the following criteria. Both criteria, GSR and PPG, have been utilized by Maltzman (1965) in his research.

GSR for Condition I. Only those GSRs of greater than 400 ohms magnitude and occurring no sooner than 3 sec. and not later than 15 sec. after the onset of S_1 were reduced.

PPG was reduced for Condition I by taking the direction and magnitude of the 1st change occurring 3 sec. or more after the onset of S_1 and up to 15 sec, and then the opposite direction and magnitude was recorded as the second phase of the response. PPG was reduced to the nearest mm.

The same criteria used in Condition I for GSR and PPG were applied in Condition II and III for responses to both S_1 and S_2 .

In Condition II, three types of GSRs were looked for.

1. GSRs to S_1 .
2. GSRs occurring more than 5 sec. after S_1 offset but before S_2 , i.e. an "anticipatory GSR".
3. GSRs to S_2 .

For Condition II, only PPGs to S_1 and S_2 were reduced as it would have been extremely difficult to detect any anticipatory PPGs to S_2 without the aid of a computer averaged transient analysis.

In Condition III GSRs to S_1 were reduced and any GSRs and it's point of onset 5 sec. after S_1 and up to 30 sec. thereafter were reduced. Anticipatory GSRs were those occurring before 15 seconds after S_1 and violation of expectancies were those GSRs occurring more than 18 seconds after S_1 offset, (15 sec + 3 sec.).

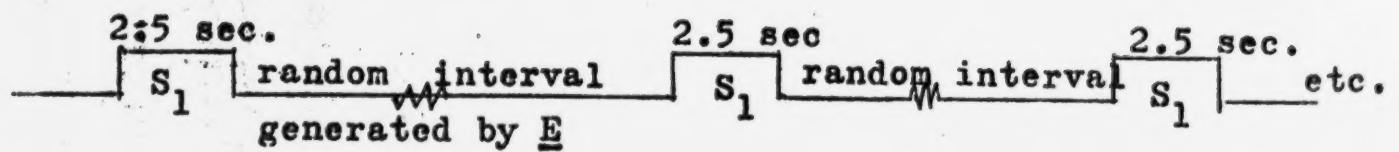
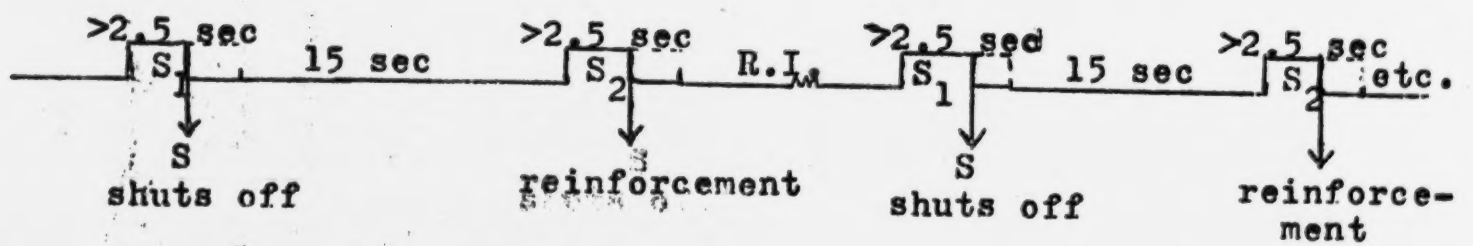
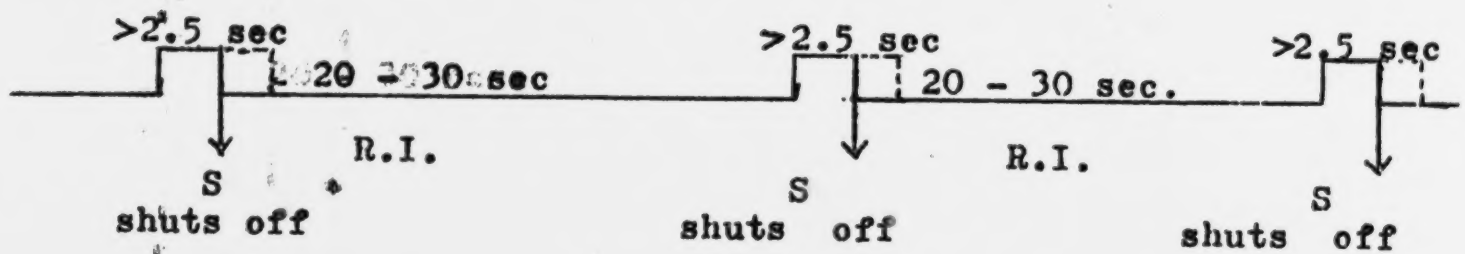
CONDITION ICONDITION IICONDITION III

Fig. 1. Event Diagram for the Three Conditions.

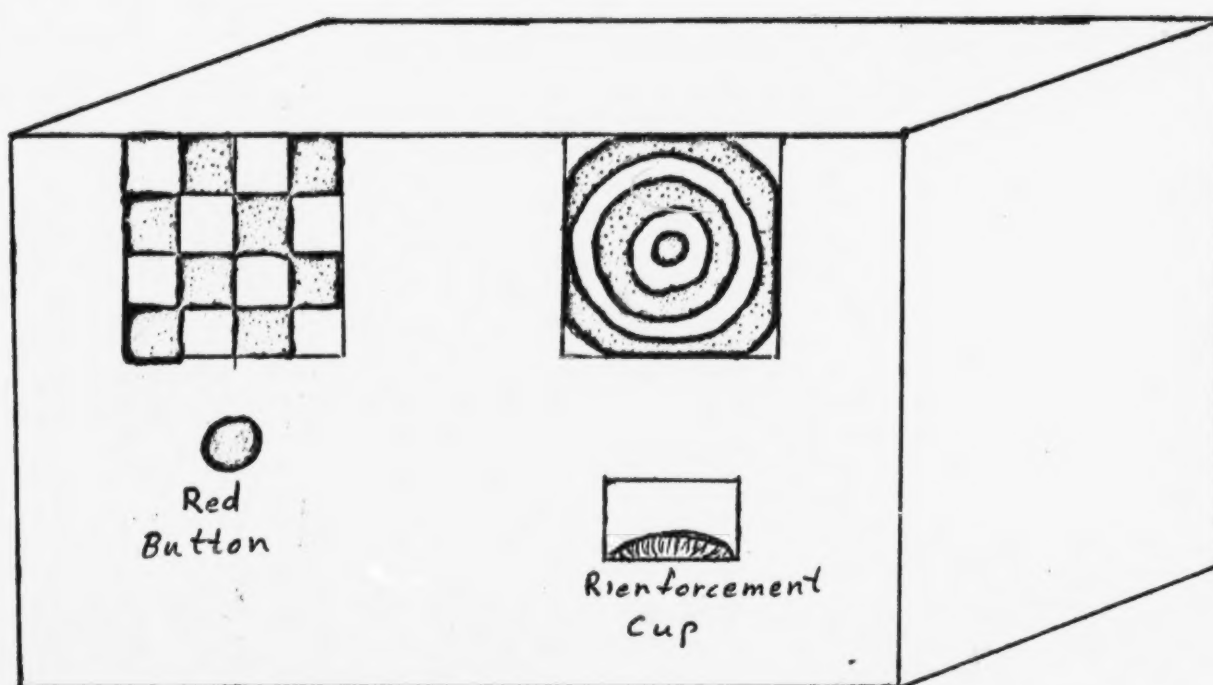


Fig. 2. Design of Stimulus Apparatus

RESULTS

Fig. 3 shows the GSR of Subj. 1, male, to stimulus 1, ^(S₁) the left light, over nine pre-test trials. There appears to be a progressive habituation over the series as expected, with a brief reinstatement in Condition 3 & 7.

Fig. 4 indicates the habituation rate of Subj. 2, female, to the left light, S₁. There is, again, a progressive habituation with two brief reinstatements at trial 7 & 9. Thus, both Subj.'s GSR habituated in a predictable manner.

Fig. 5 compares the GSR and PPG of Subj. 1, male, over Cond. I. The first presentation of S₁ elicited a vasodilation or "orienting response, (OR). However, subsequent responses were nearly all vasoconstrictions, or "defensive responses", (DR). The only apparent correlation between the PPG and GSR, herein, seems to be that lower GSR values correspond to DRs and the two highest GSR values to either ORs or no PPG response.

Fig. 6 presents both the GSR and PPS of Subj. 1, over Cond. I, left light presentation, S₁. The first two presentations of S₁, produced ORs, but eight of the remaining ten S₁s yielded DRs.

The mean GSR for both subjects across Cond. I was 1100 ohms. The mean magnitude of DRs and ORs were approximately equal for both subjects across Cond. I.

Fig. 7-A compares the GSR of Subj. 1, male, to S₁ and S₂ + R⁺ across Cond. II. Anticipatory GSRs to S₂ have been charted in red triangles, with their latency recorded adjacent. The habituation to S₁ and S₂ slightly parallel each other. However, the mean GSR to S₁ is smaller than to S₂, (1214 < 1857 ohms). Through trial 5, GSRs to both S₁ & S₂ appear to be habituating. Beginning at the 5th trial with the appearance of the first anticipatory GSR, the GSR to

S_1 and S_2 suddenly increases; with S_2 s being the larger. Anticipatory GSRs and GSRs to S_2 parallel each other in direction and slope of increase after trial 5. On trial 7, however, S_2 continues to increase and S_1 s GSR habituates, seeming to suggest that a discrimination has been made between the signal properties of S_1 and S_2 . Reinforcement properties may have, by this point, been transferred to S_2 . The first four anticipatory GSRs increase in magnitude and remain fairly stable at a mean latency of 13.5 sec. after S_1 . Trials 12-14 presented some variability in both magnitude and direction of GSR.

Fig. 7-B demonstrates the comparative GSRs of Subj. 1, through Cond. II, to S_1 and $S_2 + R^+$. This subject failed to display any anticipatory GSRs to S_2 . The GSRs to S_1 and S_2 seem to parallel each other considerably. However, there seems to be an alternation of habituation, reinstatement, habituation, and reinstatement for both S_1 and S_2 , simultaneously. Variability is the chief characteristic of this graph, however, the mean GSR to S_2 is greater than that to S_1 . After the 12th trial the GSR to S_2 begins to exceed the GSR to S_1 .

Fig. 8 presents a comparison of Subj. 1, male's, GSR and PPGs over Cond. II, to only stimulus 1. Eleven out of the fourteen PPGs are DRs, or vasoconstriction, followed by vasodilation. Only two of the PPGs are ORs, or vasodilation first, seeming to bear no relationship, in case of the ORs, to the concurrent changes in GSR. There appears to be a pattern of decreasing amplitude of DRs and ORs over several trials and then a sudden increase followed by another run of decrease.

Fig. 9 shows the PPGs and GSRs of Subj. 1, over Cond. II, but only to $S_2 + R^+$. Nine out of fourteen PPGs were DRs with a slight decrease in the number of DRs to S_2 as compared to the number of DRs to S_1 . All three of the ORs correspond to high values or suddenly increasing values of GSR. On trial 9, there is a sudden jump of GSR with an accompanying absence of PPG. This was also seen in Fig. 5 for a response of the same subject to S_1 . In trial 12, where a sudden anticipatory GSR occurs at about 8 sec., there is a very large DR.

Fig. 10 compares the GSRs and PPGs of Subj. 2, female, over Cond. II, for S_1 . It may be noted that for Fig. 7-B, this subject's GSR was extremely variable and so, with the corresponding PPGs. Thirteen out of nineteen PPGs were DRs. The ORs do not seem correlated with either suddenness of change or magnitude of GSR. Four of the first five presentations were DRs and three of the last four were DRs.

Fig. 11. Here we find a comparison of GSRs and PPGs for Subj. 2, female, to $S_2 + R^+$. Sudden large increases in GSR seem correlated with very large DRs. Fifteen out of nineteen of the PPGs are DRs. No anticipatory responses were observed.

Fig. 12 is Subj. 1's, male, GSRs to the critical test Cond. III. S_1 is presented and then responses during the following empty interval are recorded. The point at which anticipatory GSRs to S_2 occurred was recorded, as were "violations of expectancies" more than 15 sec. after S_1 . Four anticipatory GSRs occurred with a mean of 14 sec. after S_1 . Reinstatement trials were interspersed through this condition and seemed to maintain the behavioral attention

of the subjects. The mean anticipatory GSR was greater than the mean GSR to S_1 , (1760 > 1183 ohms).

Fig. 13 is Cond. III for Subj. 1, male's, GSRs and PPGs. Most of the PPGs, here, to S_1 , are DRs and most of those to S_2 are ORs. It is difficult to detect any extensive parallel between the GSRs or PPGs in either magnitude or direction. It is of interest to note that whether the PPGs to S_2 is OR or DR, it is typically larger than the PPGs, (OR or DR), to S_1 . Three of the four anticipatory GSRs are accompanied by an OR. Only the fourth evidenced NO PPG. The last three trials of this condition showed no PPG change.

Fig. 14 is Subj. 2, female's, GSRs to Cond. III, S_1 . Any anticipatory GSRs or "violation of expectancies" are also recorded. Three of the five GSRs were longer than 15 sec, after S_1 , on the test trials, and are, therefore, by definition of this study, "violation of expectancies". In nearly every case the GSR to S_1 , was greater than the anticipatory GSRs. However, it appears that of the first four trials, that an increase in GSR to S_1 is followed by a corresponding increase in the magnitude of the anticipatory response. This progressive increase may characterize a generalized arousal. (Note dotted curves on Fig. 14.)

Fig. 15 demonstrates Subj. 2, female's, GSR and PPG over Cond. III. Subj. 2 is far more consistent in response to S_1 , and anticipatory responses than Subj. 1 in the same condition. In nearly every test trial, the PPG to S_1 was a DR and to S_2 was an OR, and in most of these trials the magnitude of S_2 -ORs was greater than S_1 -DRs. For Subj. 2, in this condition, the largest average GSR was in the anticipatory state, the next largest being to S_2 and the smallest GSRs being to S_1 .

Without further data from a much larger population, it would be very difficult to reach any additional conclusions or meaningfully discuss, further, any of the presented results.

Enclosed at the end of this paper is the raw data for both subjects with means for GSR and PPG across all conditions.

Analysis of correlative behavioral data, such as Eye-to - Stimulus contact, would be extremely helpful in increasing the reliability and scope of this work. However, time has not permitted other than a cursory inspection of this data to date. There does appear, however, a very high correspondence between the occurrence of a stimulus and it's respective Eye-to-Stimulus contact.

DISCUSSION

In conclusion then, several of the originally set out goals have been reached.

Both subjects displayed rapid understanding of the minimal verbal instructions surrounding the test conditions. Their ability to inhibit responding, even during extinction, was far better than anticipated. To control for the possibility of counting behavior, and its effects, the children were asked at the close of the session if they had been counting during the trials. Both replied, "No".

The experimental apparatus seems highly successful for application, at least to this age group. Even though the sessions ran thirty minutes, the attention of the subjects was excellent.

In addition, we have been successful in charting the acquisition of a temporally conditioned response both as an anticipatory phenomenon and as a violation of expectancy. The stability of the

temporally conditioned.

temporally conditioned response was surprising. Moreover, artifacts in both autonomic channels were kept at a minimum demonstrating the complete feasibility of recording physiological data, at least for this age group, for these two autonomic measures.

It has additionally been demonstrated that children's fears surrounding this type of experimental situation can be overcome. It is basically essential that they be carefully, verbally prepared and adjusted to anticipate a game situation.

The conditioning design has, in general, proved extremely successful for obtaining temporal conditioning. There has also, within the present pilot work, developed an apparent distinction between the occurrence of anticipatory GSRs and a violation of expectancy GSRs.

Strong correlations between PPG and GSR would be difficult to obtain within the present study, due to the paucity of data. However, basic trends do seem suggested. There appears to be a slight correlation between sudden increases in GSR and the occurrence of DRs in the PPG. It has also been demonstrated that a highly accurate temporal expectancy can be established in this age for both male and female. Therefore, the basic trends of this pilot work have laid the groundwork for the proposed subsequent, expanded project. The use of the current equipment and experimental procedure can now be expanded into a larger, cross-sectional project to establish much needed normative profiles of temporal discrimination.

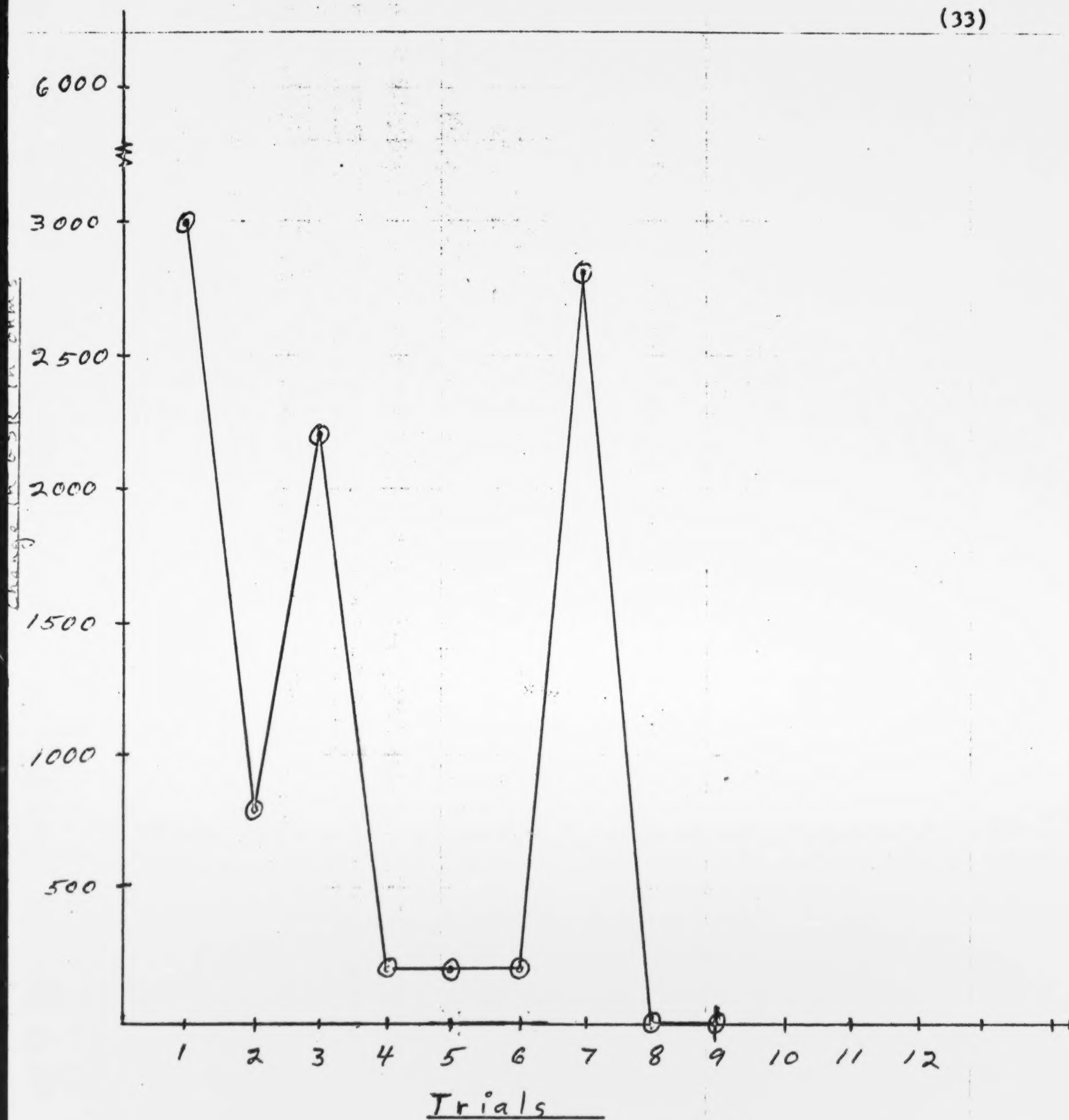


Fig. 3. Galvanic Skin Response for Subject I, male,
Condition I, Pre-test.

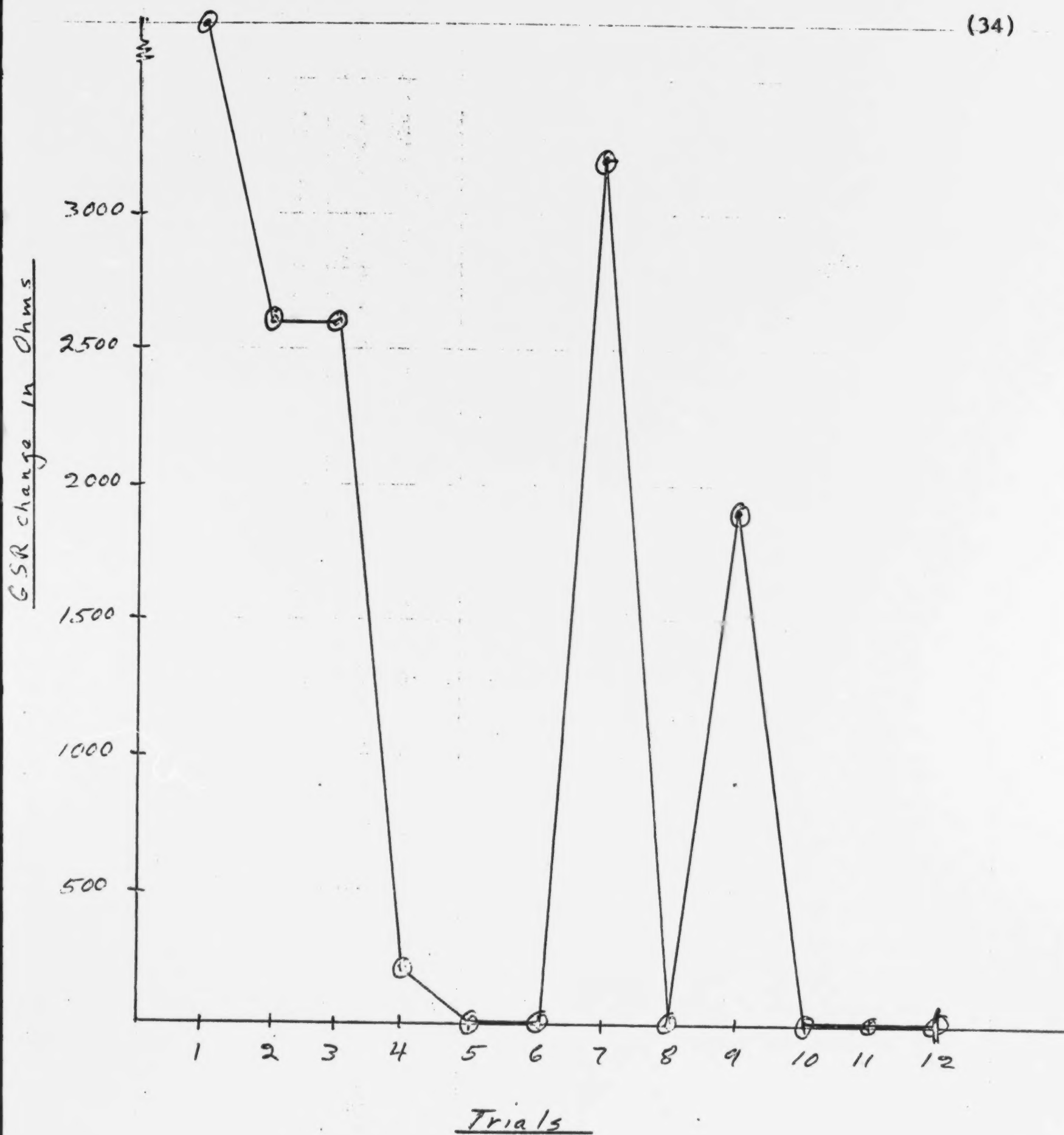


Fig. 4. Galvanic Skin Response for Subject II, female, Condition I, Pre-test.

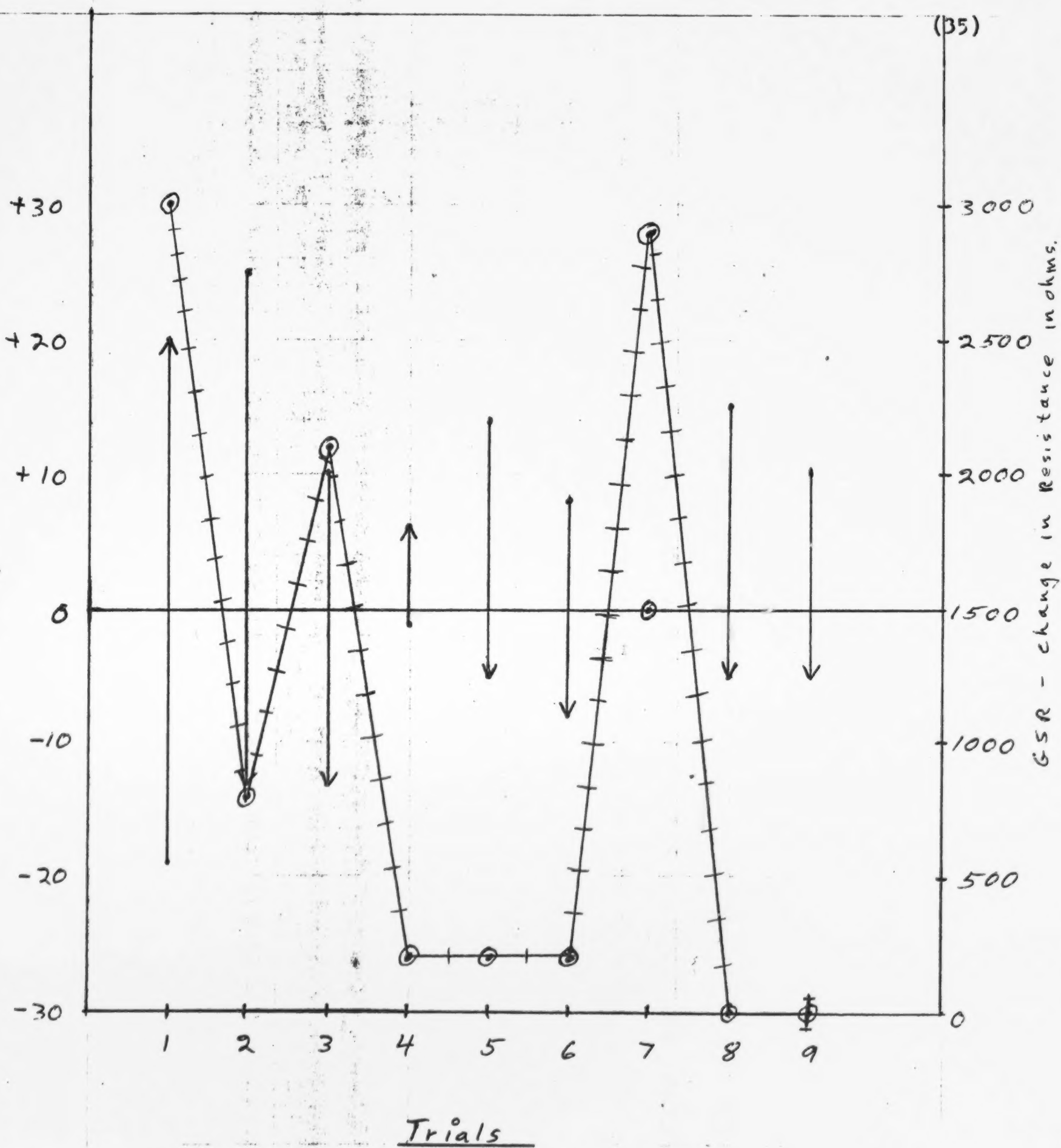


Fig. 5. Photoplethysmograph and Galvanic Skin Response of Subject I, male, to Condition I.

● = G.S.R.

↑ = PPG, vasodilation

↓ = vaso constriction

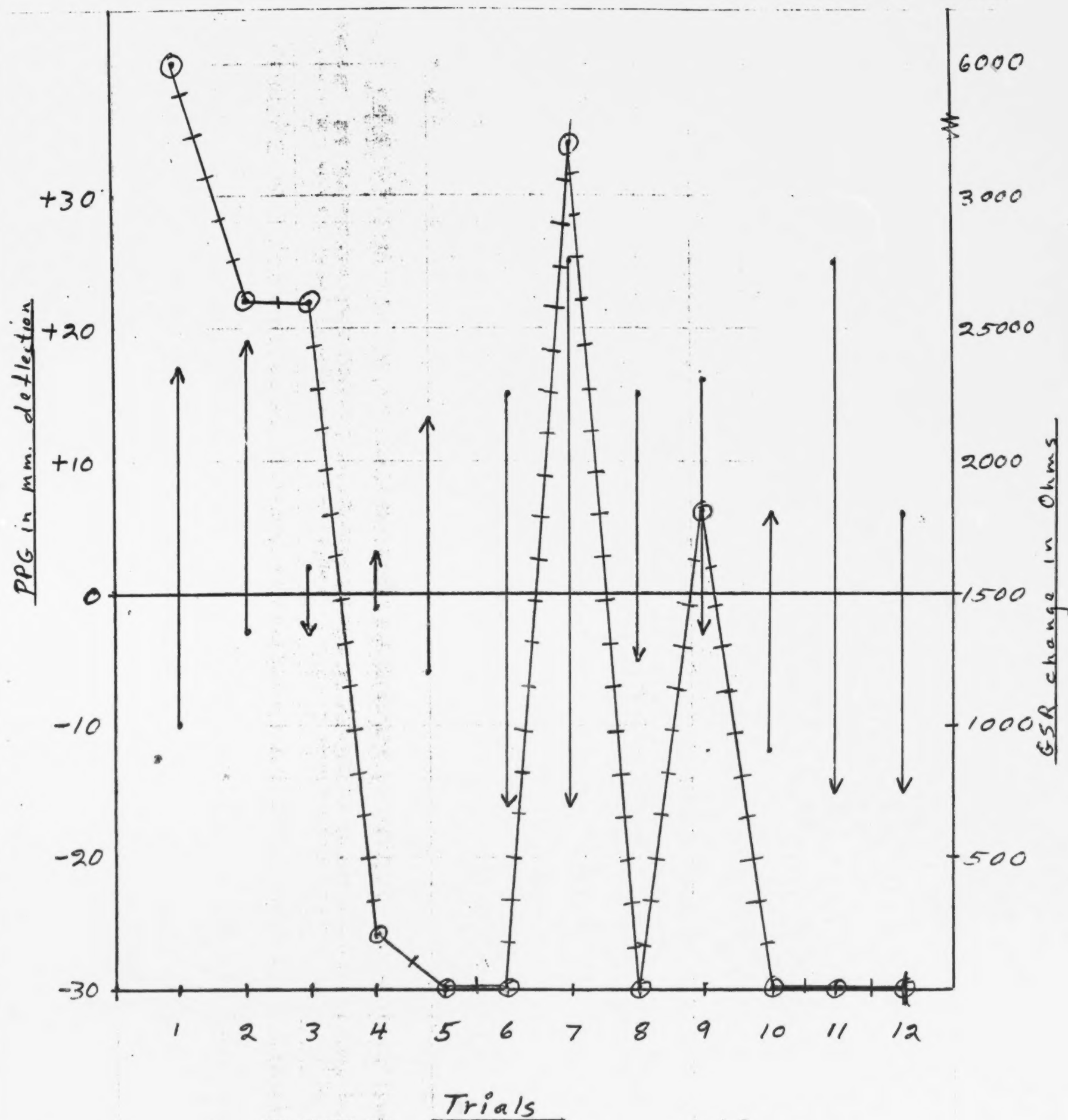


Fig. 6. Photoplethysmograph and Galvanic Skin Response of Subject II, female, to Condition I.

•+• = GSR.

↑ = PPG, vasodilation, ↓ = vasoconstriction

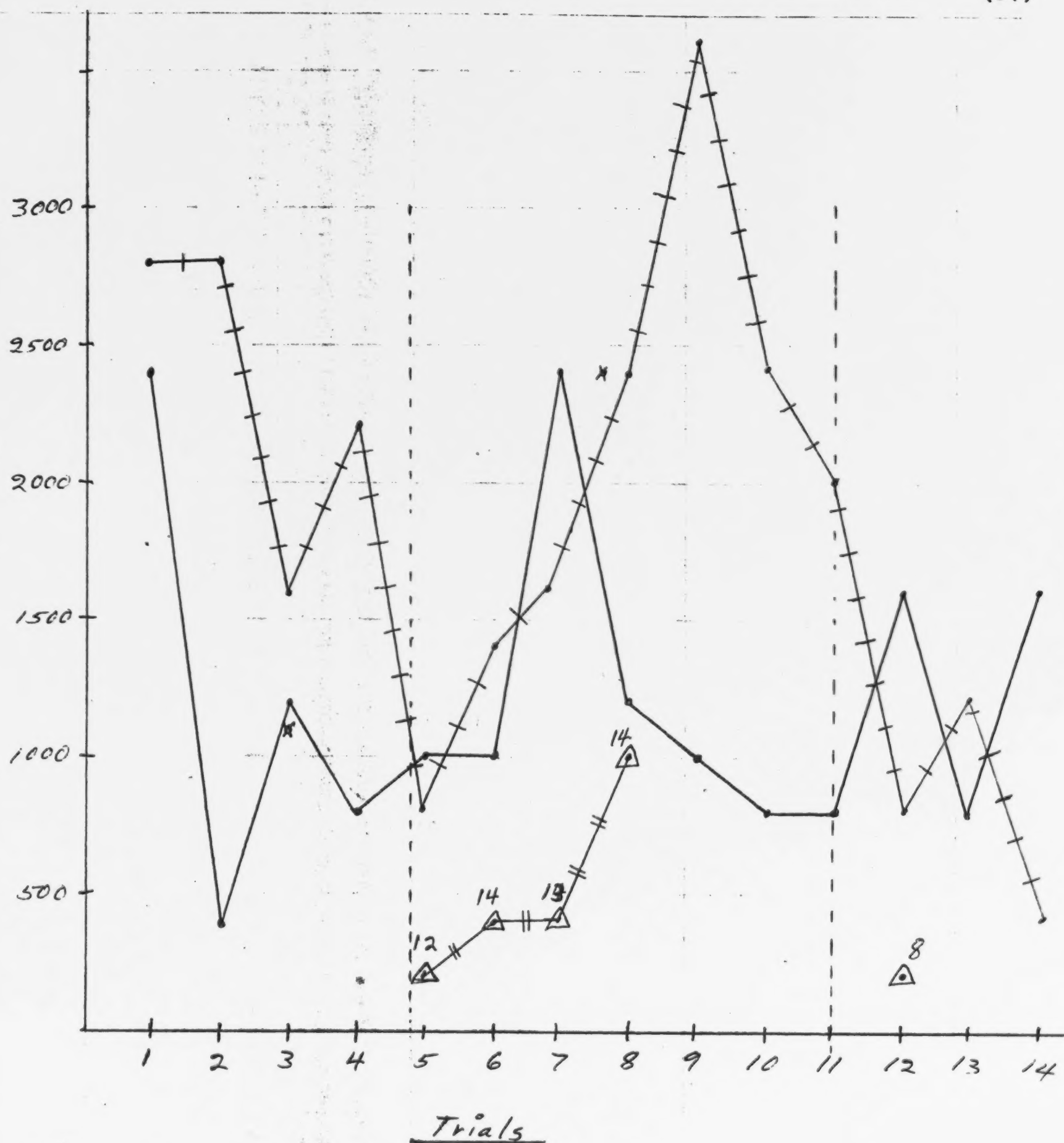


Fig. 7A. Galvanic Skin Response of Subject I, male, to Condition II. Conditioning Phase

—•— = GSR to S_1

Δ^* = #sec. after S_1 ; occurrence of anticipatory response.

—+— = GSR to S_2

Δ — Δ = Anticipatory GSR to S_2 . Latency recorded above Δ .

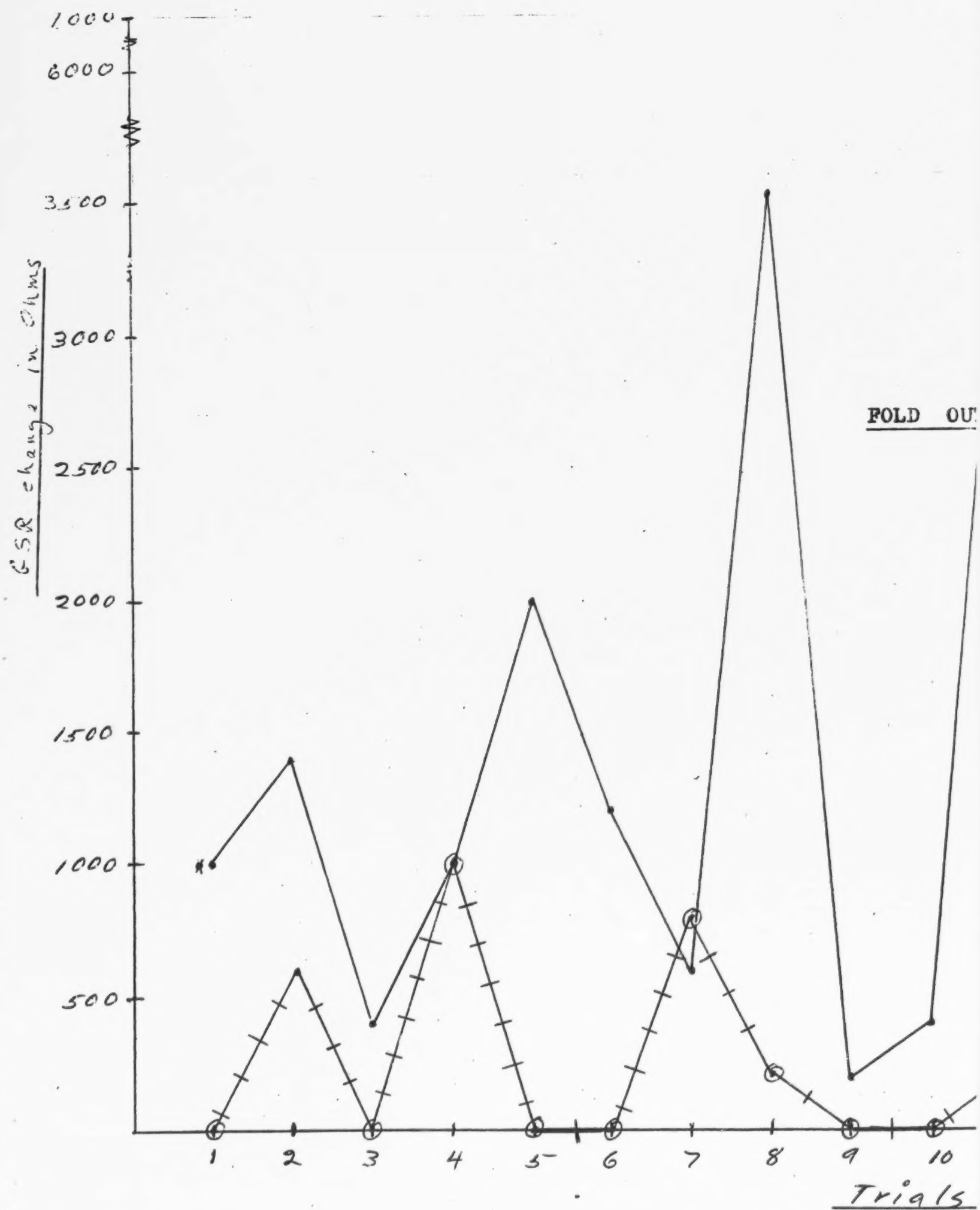
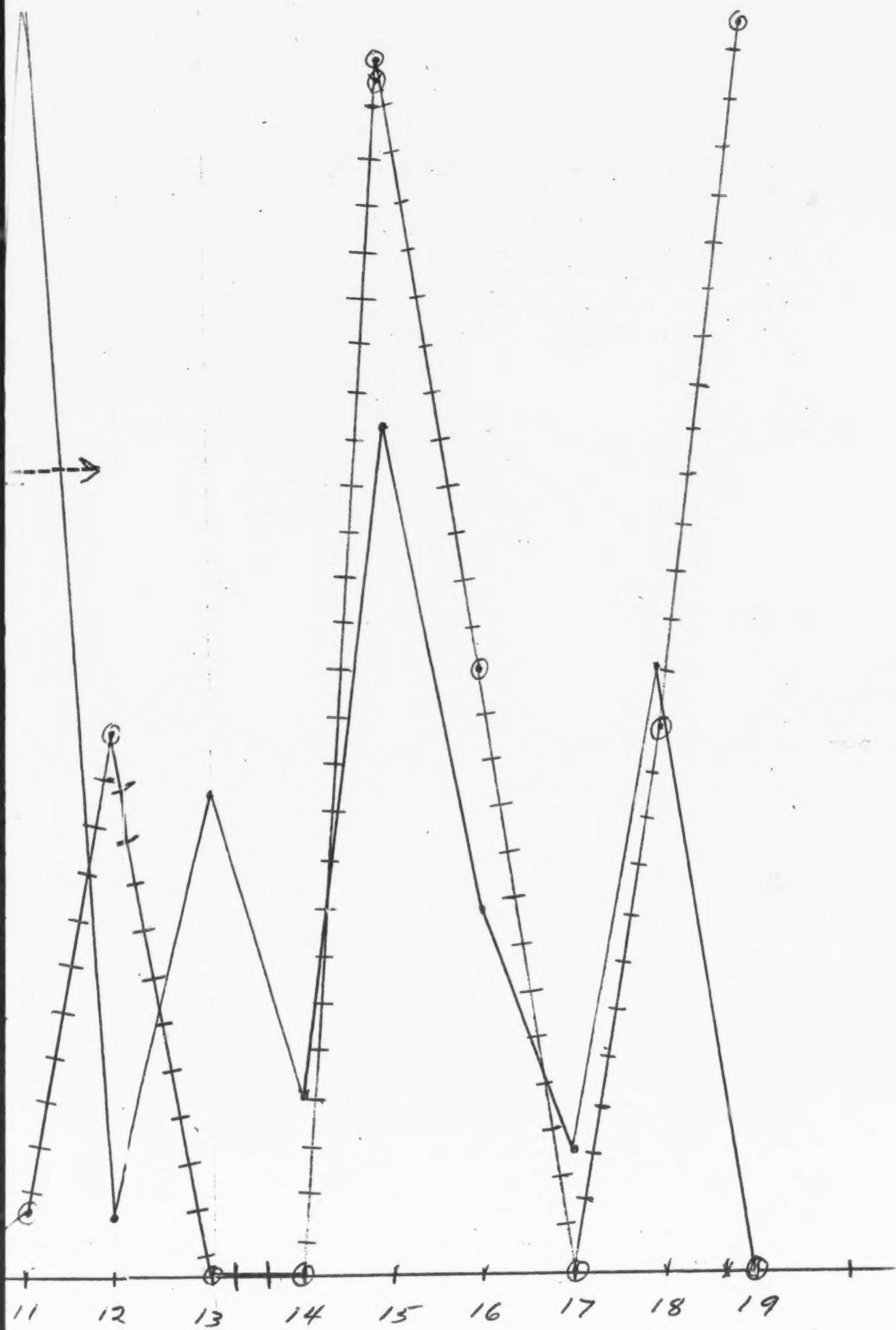


Fig. 7B. Galvanic Skin Response of Subject II, female, to Condition II. Conditioning Phase.



—•— = GSR to S_1

—○— = GSR to S_2 (No Anticipatory Responses)

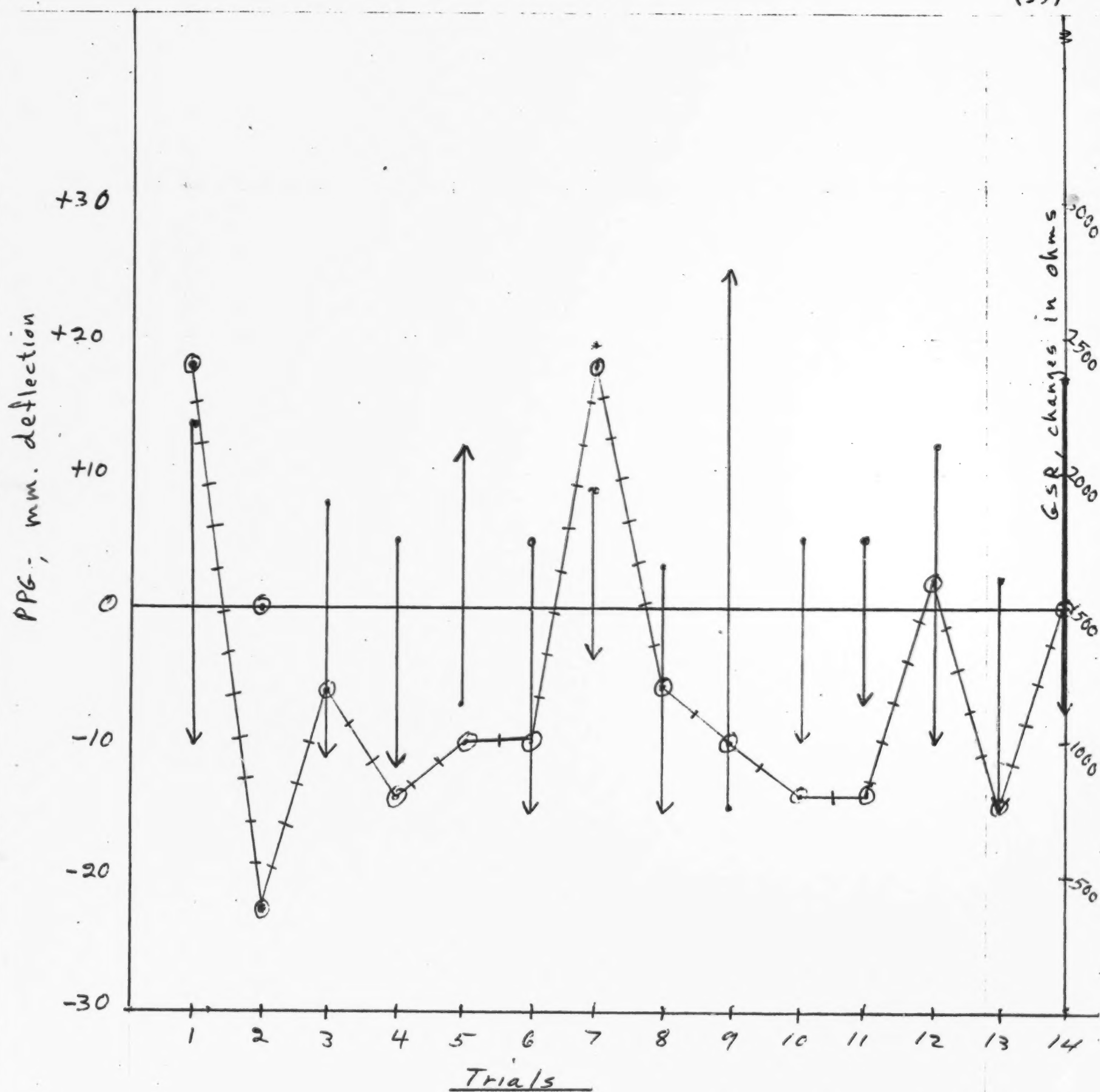


Fig. 8 . Galvanic Skin Response and Photoplethysmograph of Subject I, male, to Condition II, S_1 .

↑ = Vasodilation to S_1 , ↓ = Vasoconstriction to S_1 ,
 * = GSR to S_1 .

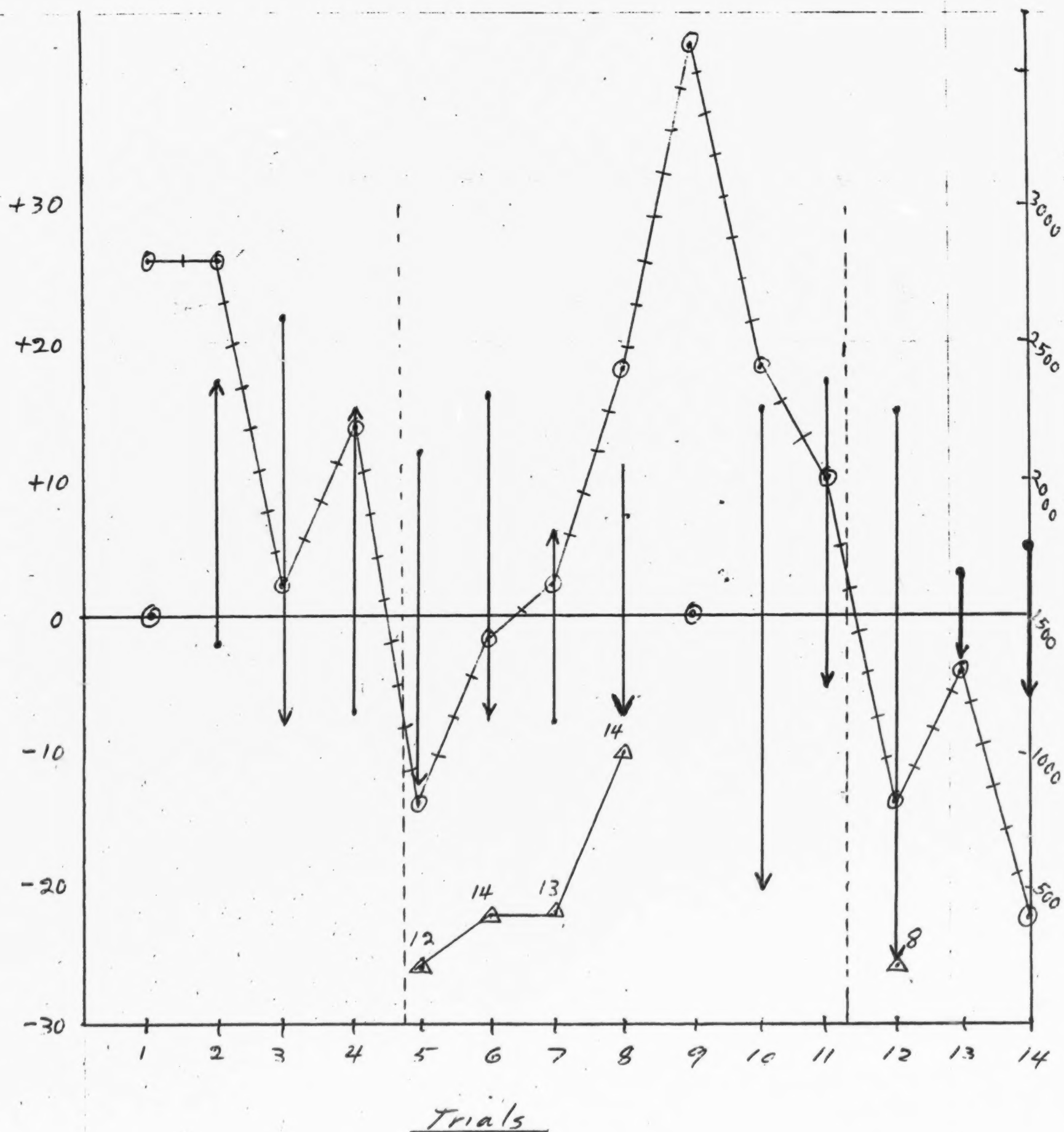


Fig. 9. Photoplethysmograph and Galvanic Skin Response of Subject I, male, to Condition II, S₂.

↑ = Vasodilation to S₂, ↓ = Vasoconstriction to S₂
 ⊙ = GSR to S₂
 △ = Anticipatory GSR to S₂

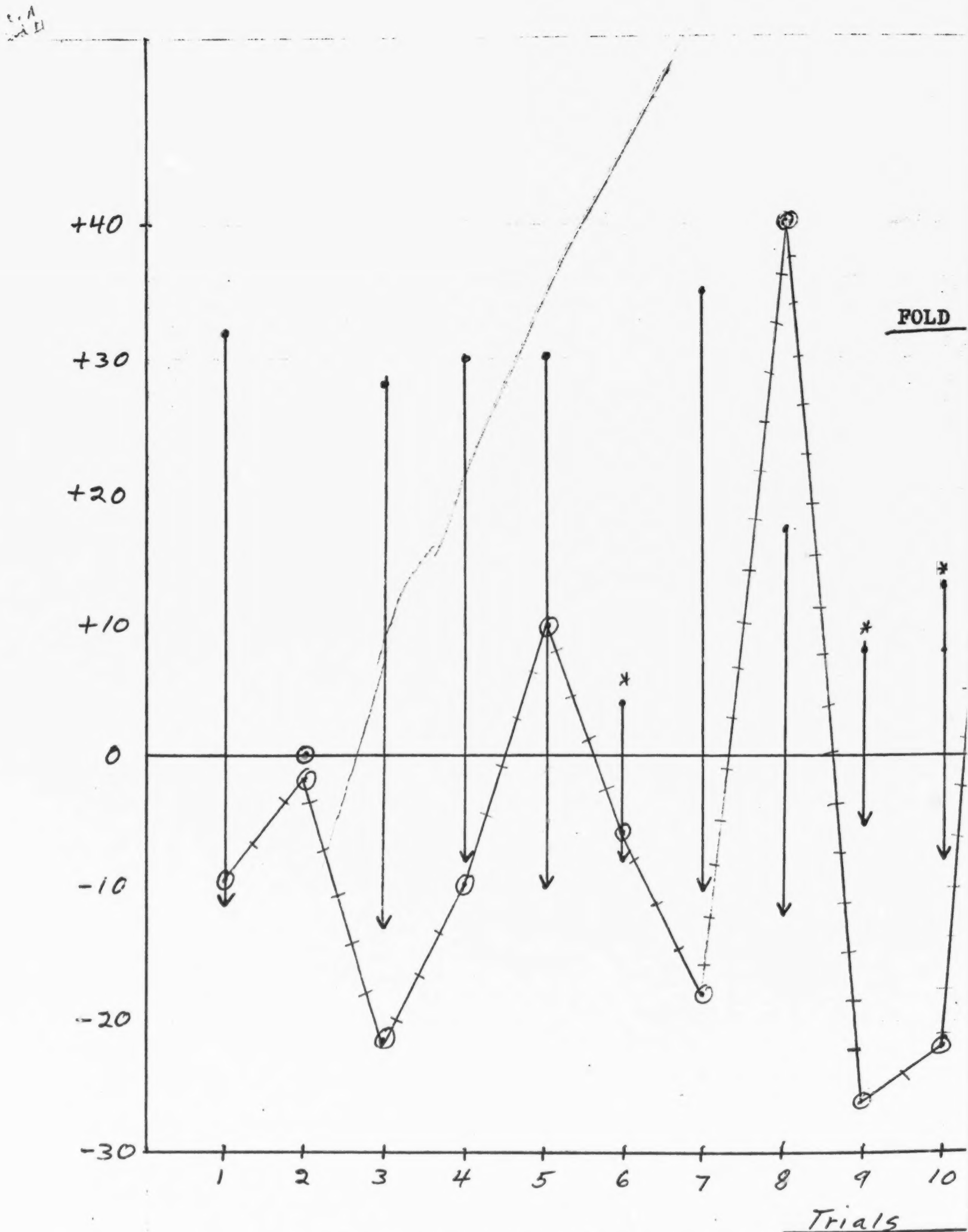
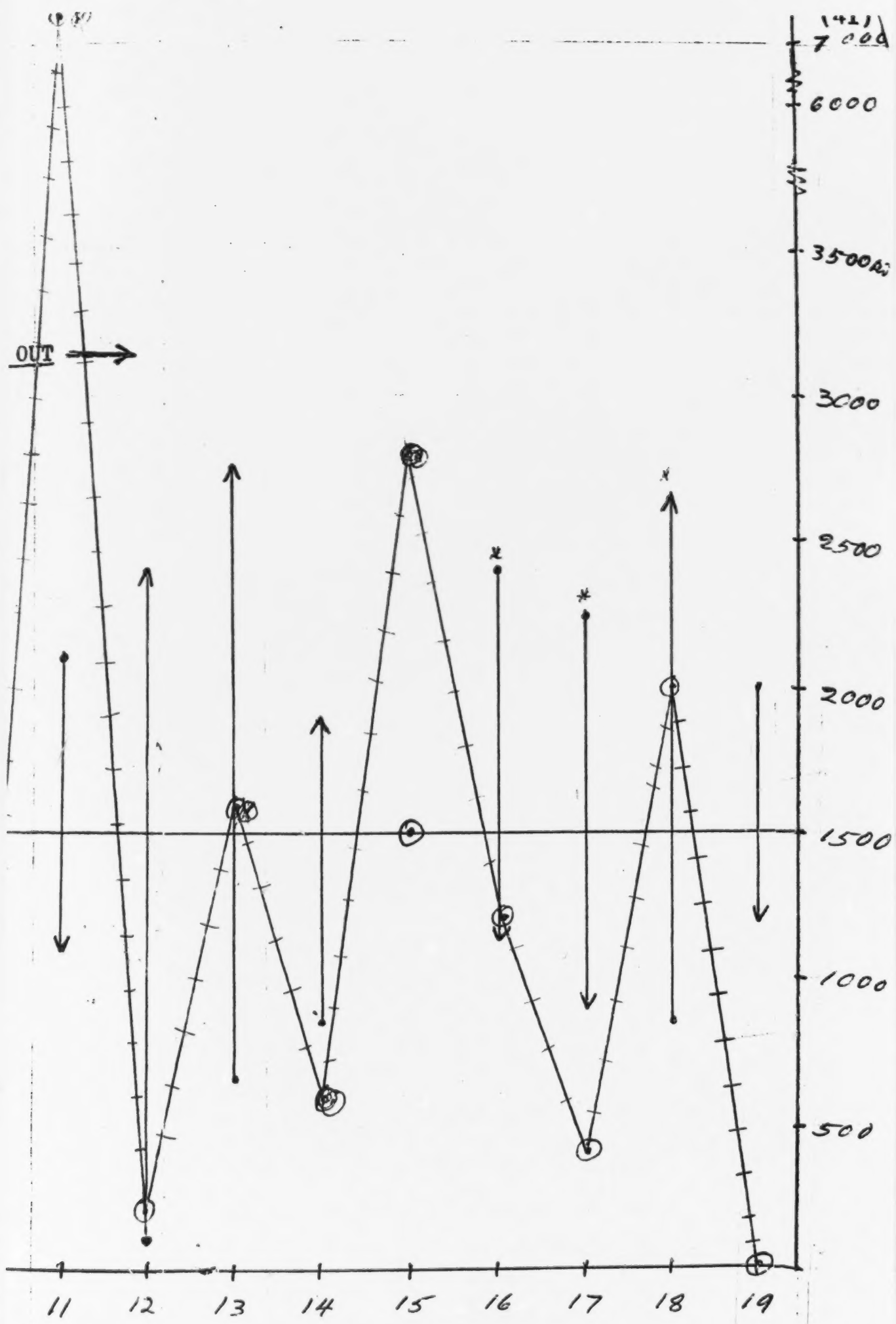


Fig. 10. Galvanic Skin Response and Photoplethysmograph of Subject II, female, to Condition II, S.



↑ = Vasodilation to S_1 ,
 ↓ =
 —•— = GSR to S_1
 = Vasoconstriction to S_1

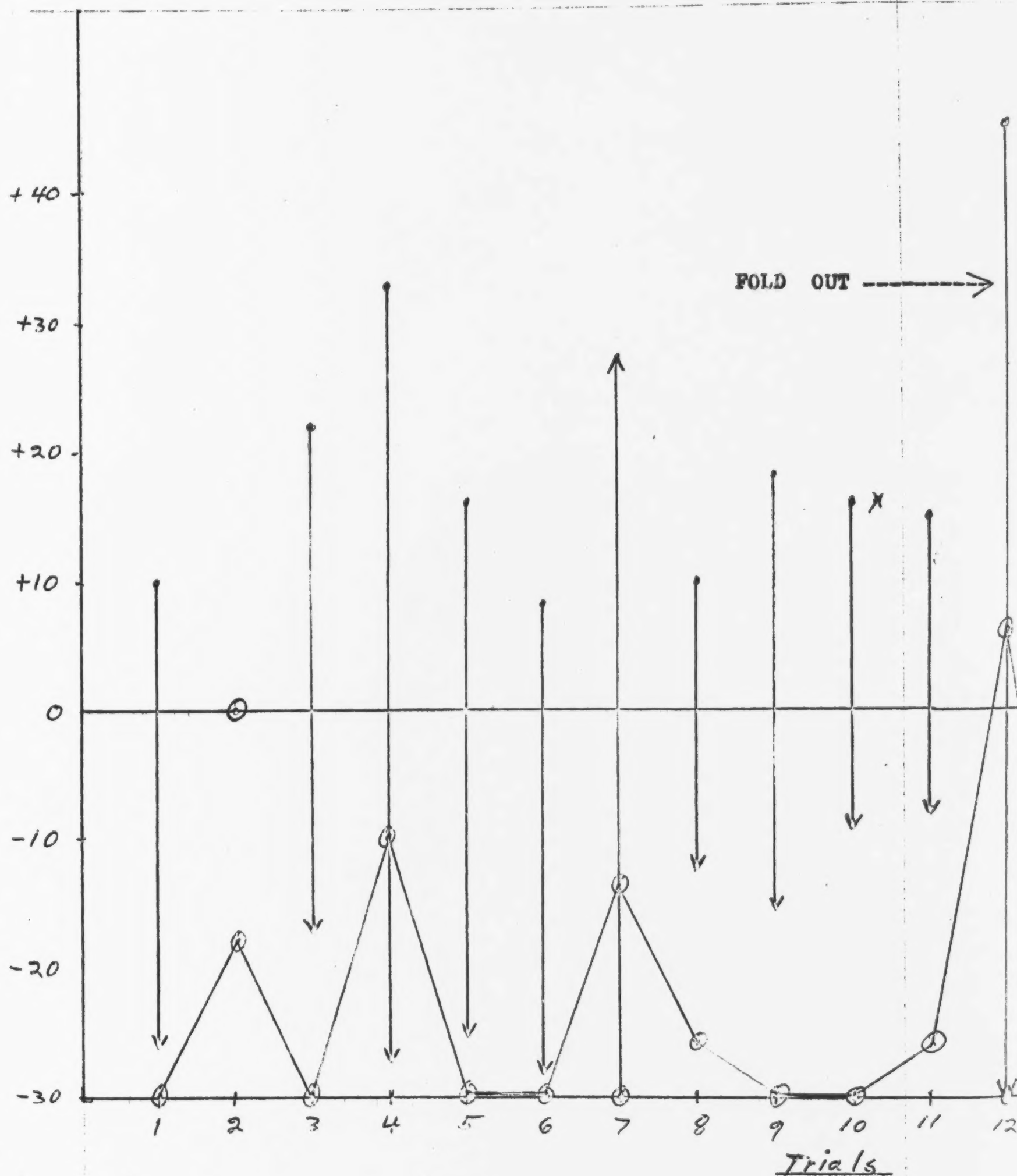
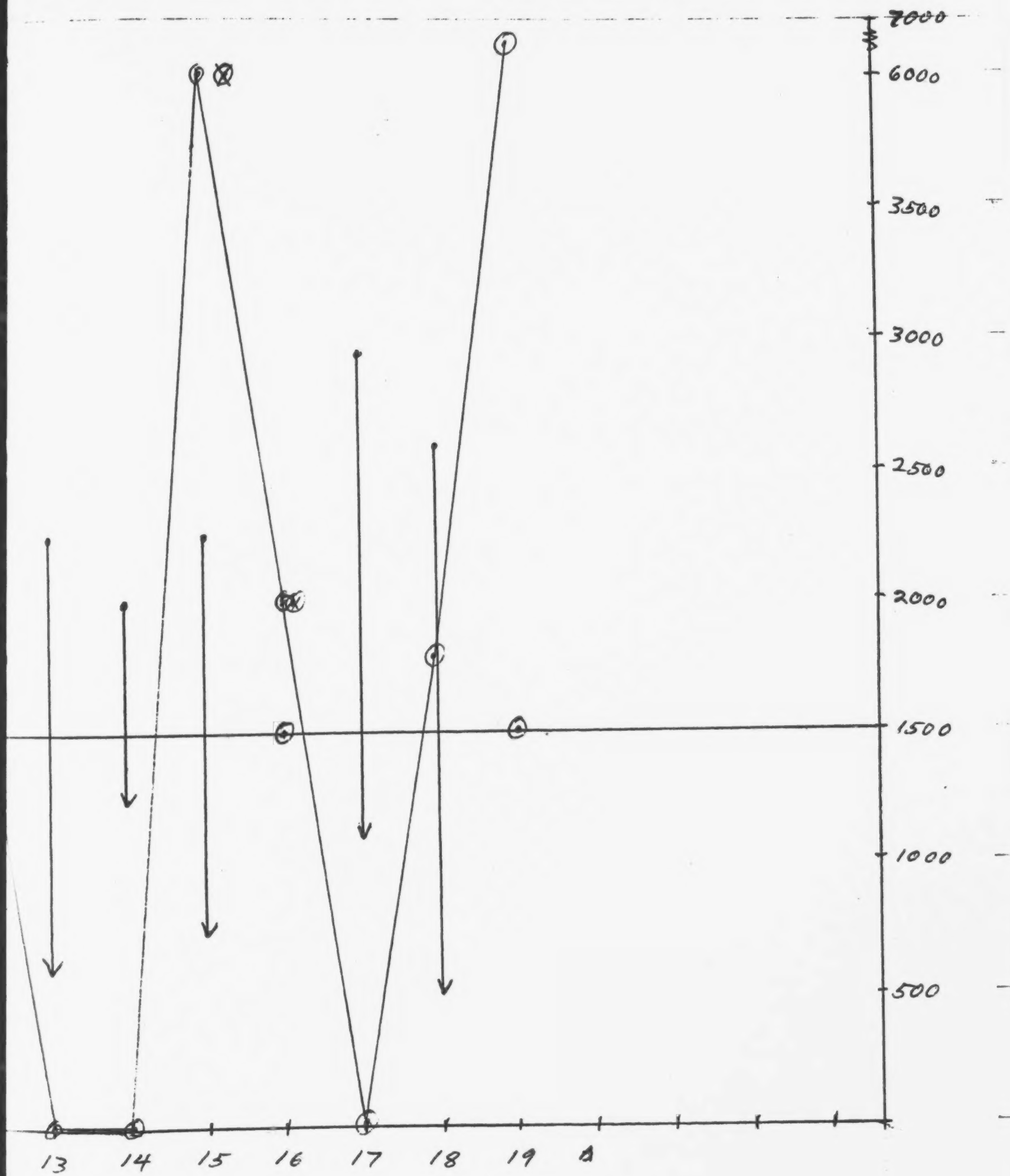


Fig. 11. Galvanic Skin Response and Photoplethysmograph of Subject II, female, to Condition II, S_2 .

↑ = Vaso dilation to S_2 , ↓ = Vaso constriction to S_2
 —○— = GSR to S_2 . (No Anticipatory Responses were



observed.

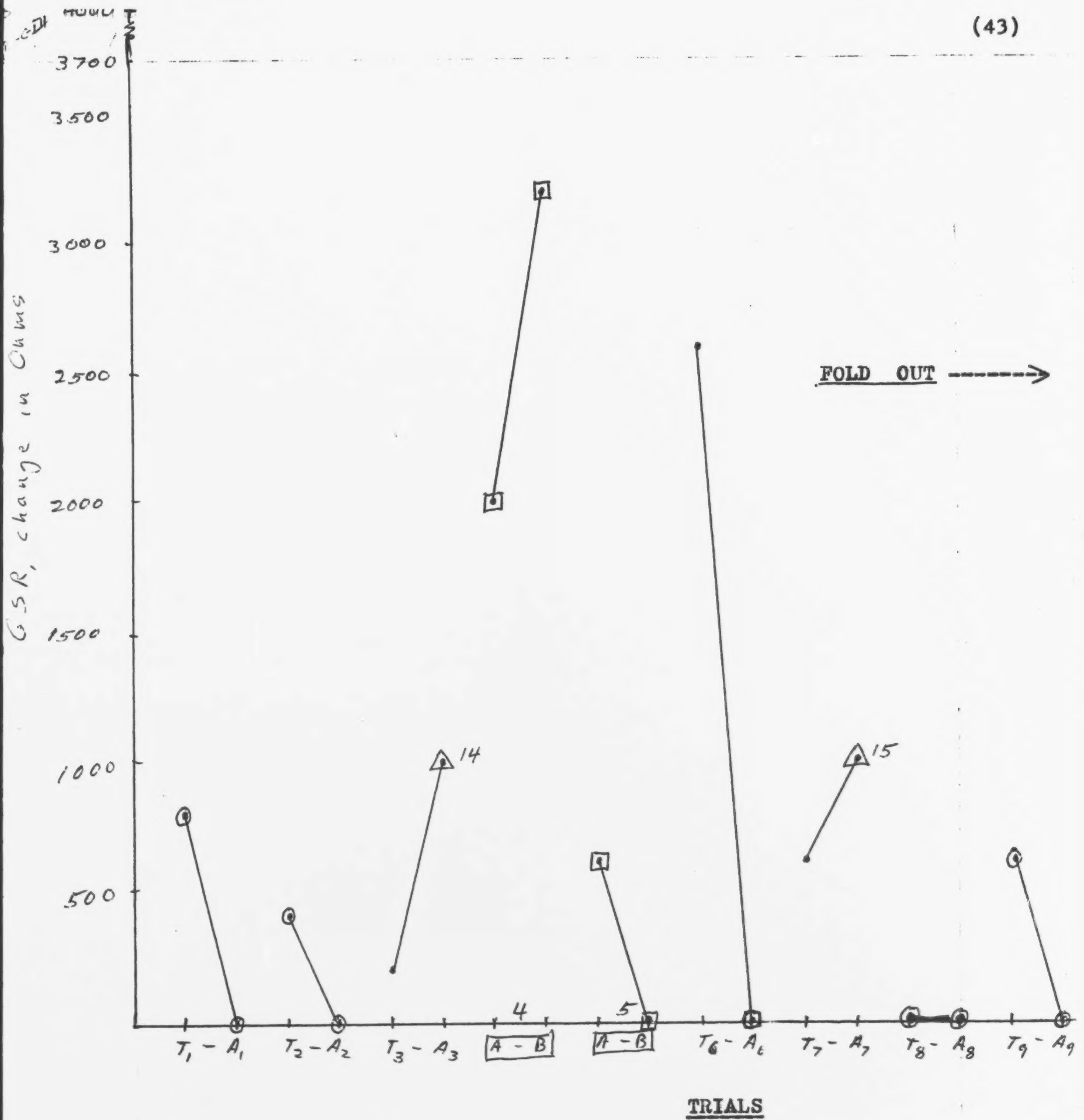
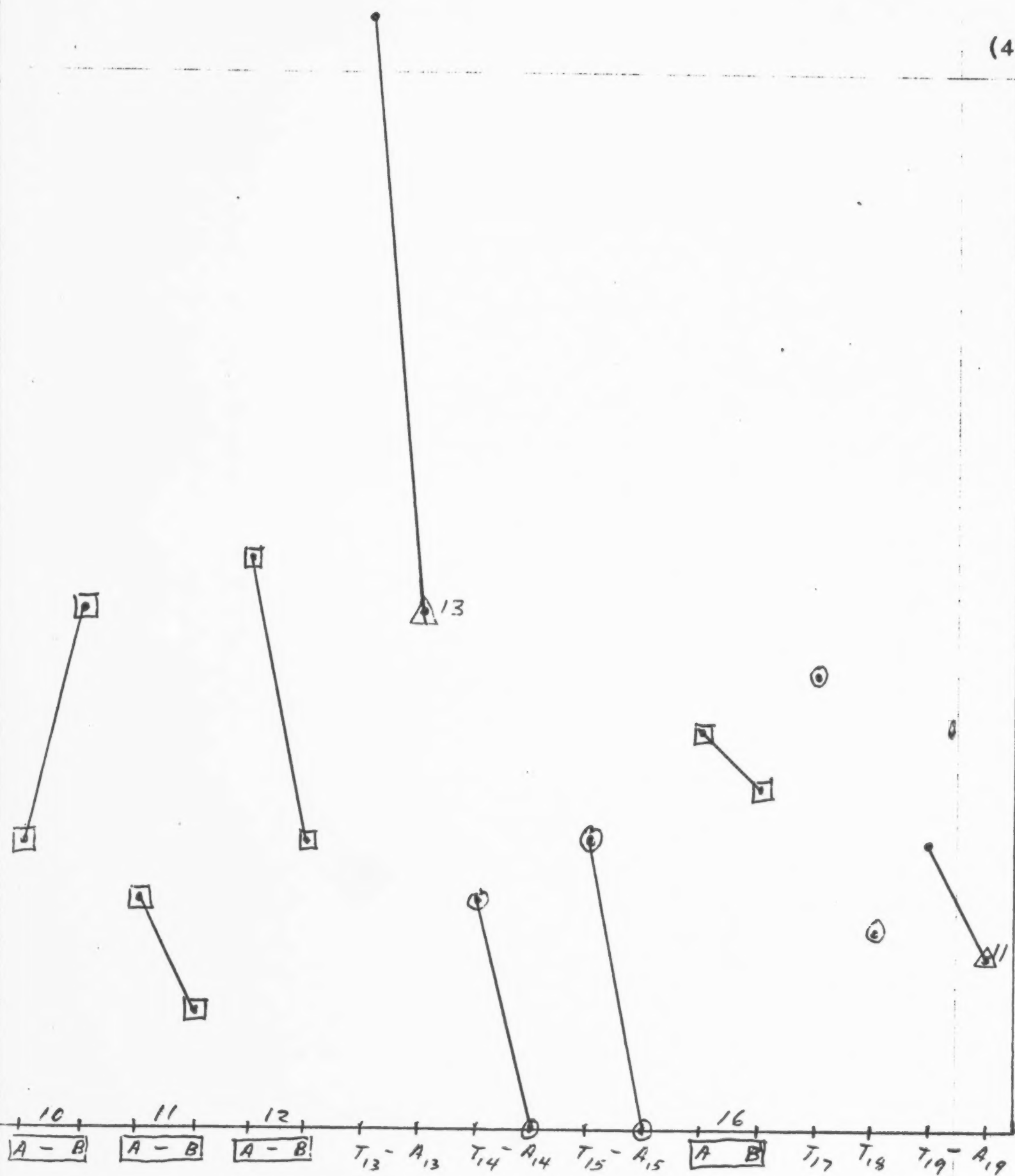


Fig. 12. Galvanic Skin Response of Subject I, male, to Condition III, S₁, and anticipatory responses and re-instatement trials.



A = Anticipatory of Violation of Expectancy responses

A - B = S₁ and S₂ - reinstatement trials

5
2 + 706
Cond III

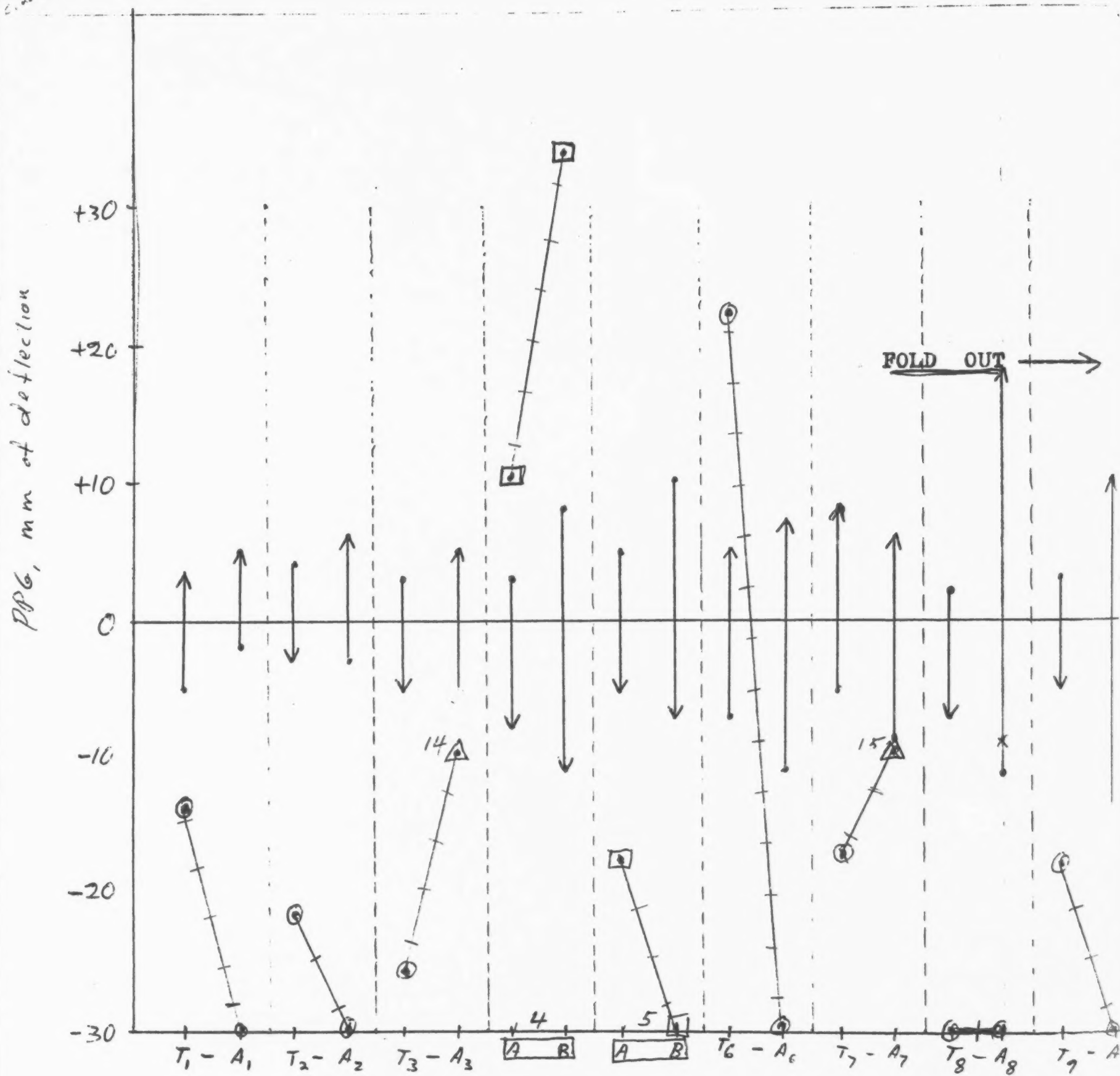


Fig. 13. Photoplytheshmograph and Galvanic Skin Response of Subject I, male to Condition III, S_1 , anticipatory responses and re-instatement trials/

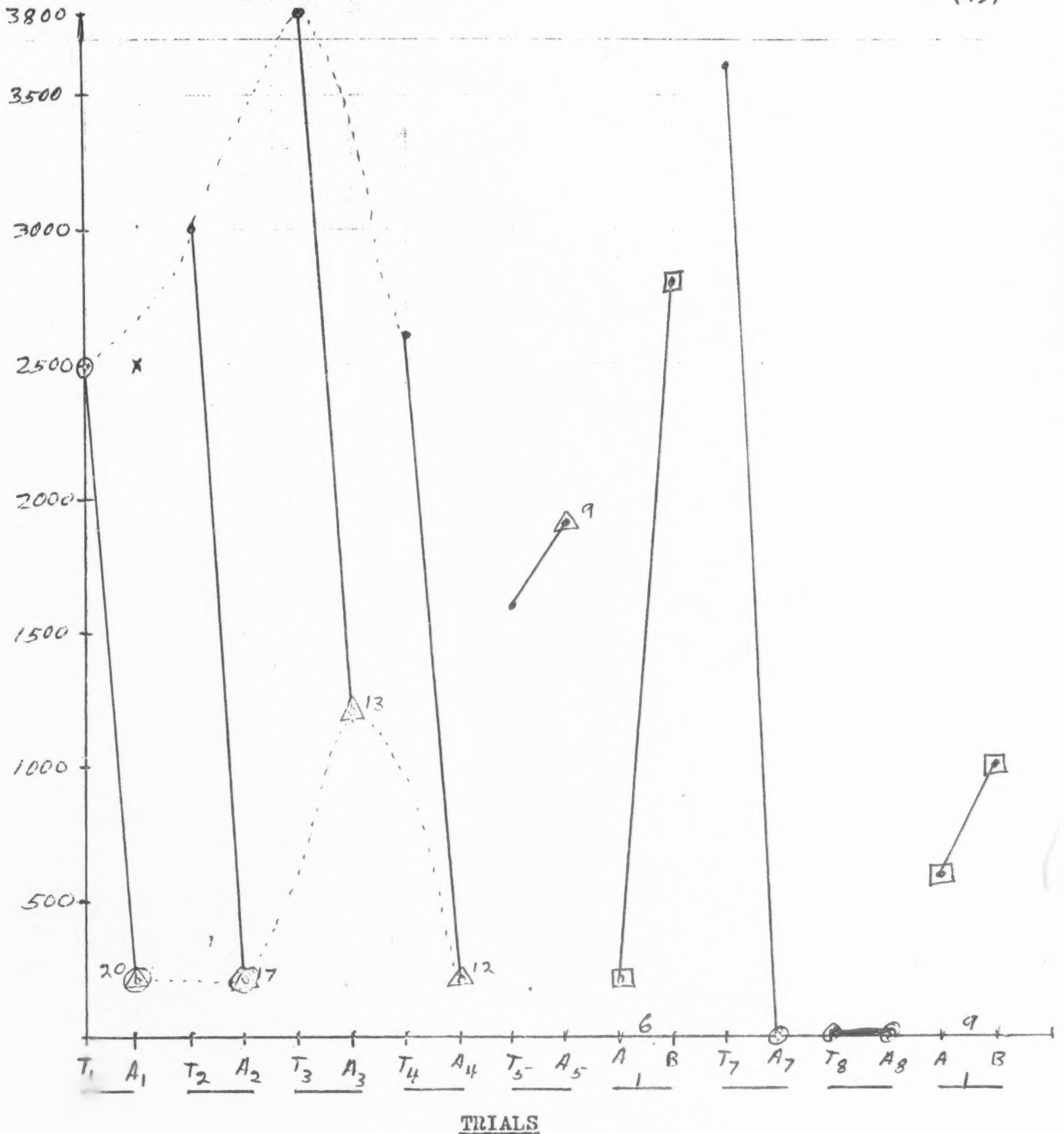


Fig. 14. Galvanic Skin Response of Subject II, female, to Condition III, (S_1 , anticipatory responses and re-instatement trials.)

T = S_1 A = Anticipatory or Violation of Expectancy responses

[A - B] = S_1 and S_2 , reinforcement trials

[] = Rein statements

T = Test stim. (S_1)
A = Anticipatory
GSR at time after S_1

⊗ = Violation of Expectancy

Δ = Anticipatory

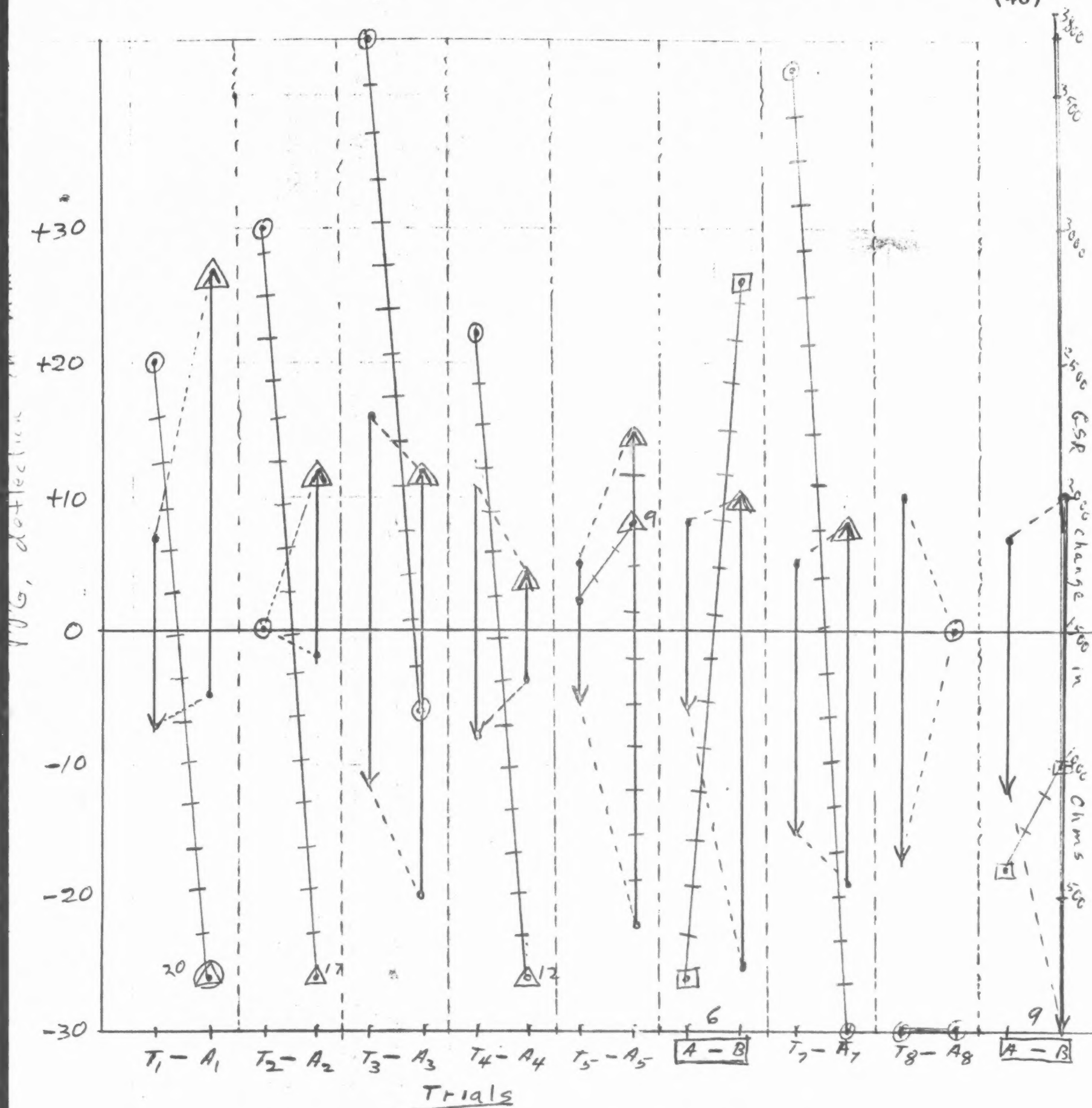


Fig. 15. Photoplethysmograph and Galvanic Skin Response of Subject II, female, to Condition III, (S_1 , anticipatory responses and re-instatement trials.)

$T = S_1$, $A - B$ = reinstatement trials

$\square$ = Reinstatements - GSR.

$\odot$ = GSR.

Δ = Anticipatory GSR.

$\triangleup$ = Violation of expectancy - GSR.

$\uparrow$ = Vasodilation to S_1 ,
 $\downarrow$ = Vasoconstriction to S_1 .

$\triangleup$ = Anticipatory vasodilation.

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